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NORTH ATLANTIC
industries, inc.

phase angle voltmeters

OPERATING AND INSTRUCTION

MANUAL FOR

VM202 S-104

PHASE ANGLE VOLTMETER

Patents are Pending for a Number of Circuits

Used in This Instrument

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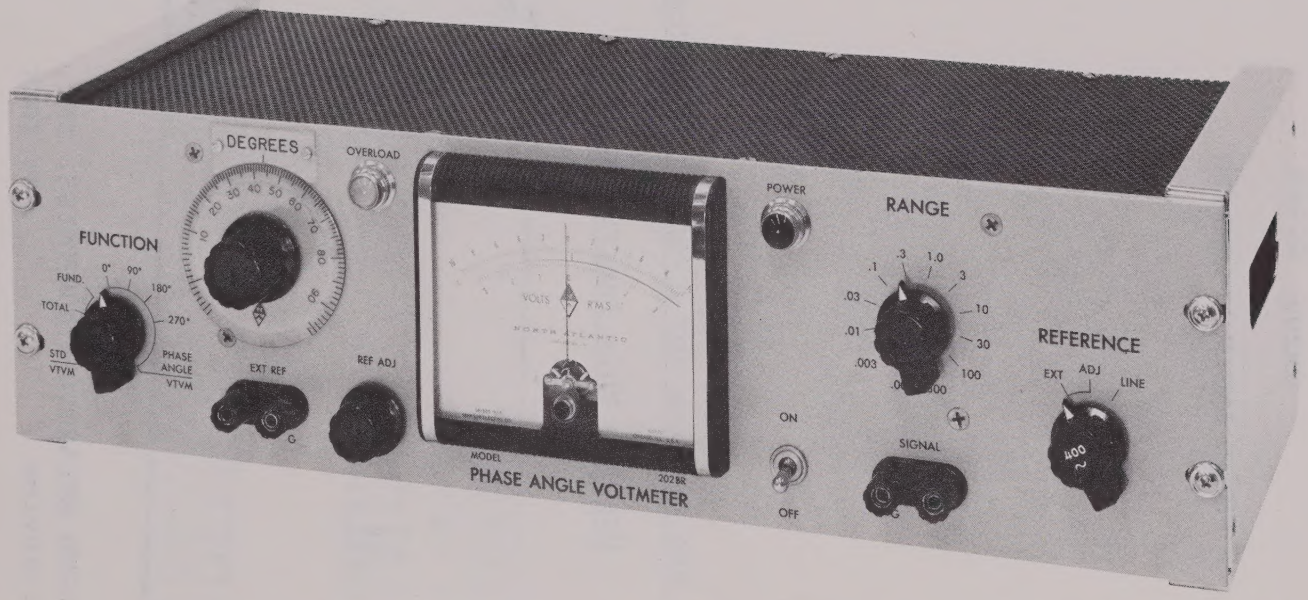
DEGREES
OVERLOAD
FUNCTION
FUND.
TOTAL
STD VTVM
0°
90°
180°
270°
PHASE ANGLE VTVM
EXT REF
REF ADJ
VOLTS RMS
MODEL 202BR
PHASE ANGLE VOLTMETER
POWER
ON
OFF
RANGE
.1
.3
1.0
.03
3
.01
10
.003
30
100
SIGNAL
REFERENCE
EXT
ADJ
LINE
400

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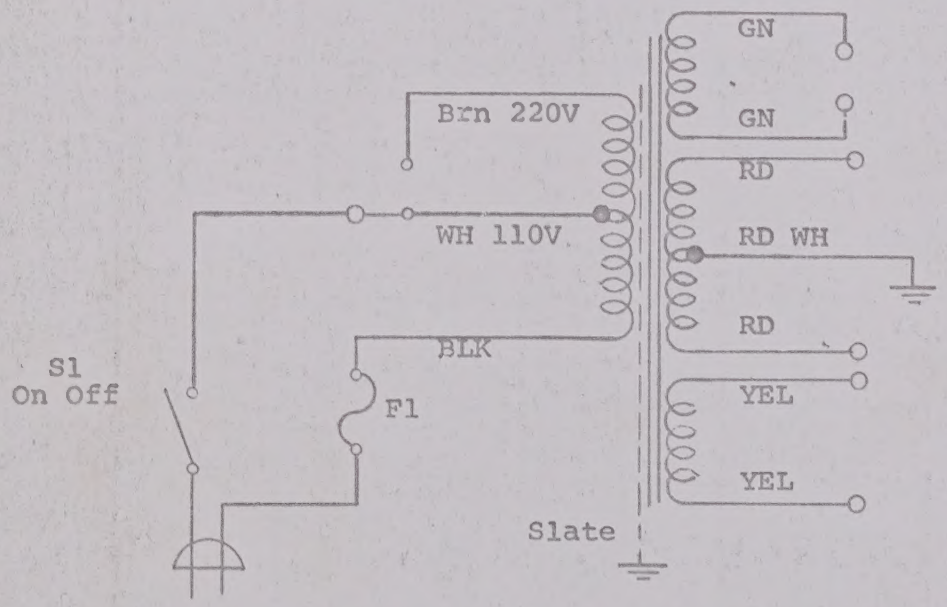
MANUAL CHANGE

TYPE 200 PHASE ANGLE VOLTMETERS

All Phase Angle Voltmeters above Serial No. 2560, may be operated from either a 110 Volt or 220 Volt, 50 to 400 cycle source. Correct operating voltage as wired at the factory is indicated on the rear panel of each instrument.

To convert from one line voltage source to the other, it is necessary to rewire the Primary of the Power Transformer. (See schematic below.) All connections are located on terminal strip in bottom left hand corner of chassis near Power Transformer.



CAUTION: Be sure to change value of fuse. For 110V operation use lamp; For 220V operation use 1/2 amp.

10/10/61

ADDENDUM 101

SUPPLEMENT

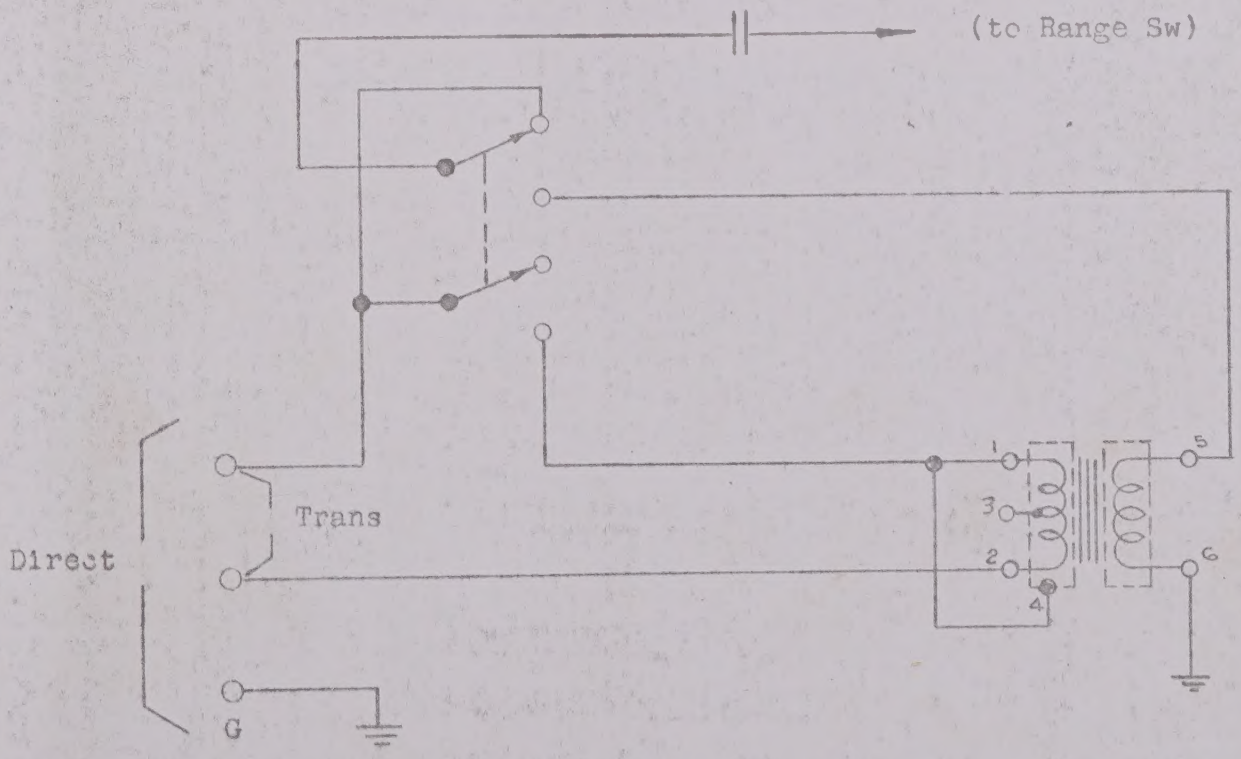
FOR

(INSTRUCTION MANUAL)

DIRECT, ISOLATED SIGNAL INPUT

This voltmeter is equipped with a transformer in the Signal Amplifier Channel which may be switched in or out for use with direct or isolated input signals. The "Direct" or "Trans" Switch located above the Reference Switch on the Front Panel when used in conjunction with the Shorting Bar on the Signal Input Terminals, allows the input to be either floated or operated with one side grounded.

Note: Internal wiring of the Isolation Transformer is such that for maximum accuracy when taking differential measurements, the lowest source impedance should be connected to the outside red input terminal of the voltmeter



Supplement Sheet #104A

INSTRUCTION MANUAL SUPPLEMENT

VM-202

The following items replace those listed in the standard replacement parts list in all instruments after S/N 6000.

Knob, Medium Pointer, 3 required, NAI #201719-1

Knob, Medium Round, 1 required, NAI #201722

Phase Dial Assembly -

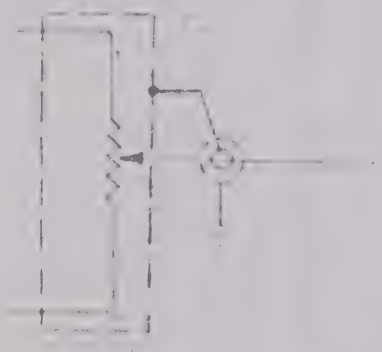
White markings, 1 required, NAI #500499

Black markings, 1 required, NAI #500498.

Supplement No. 131

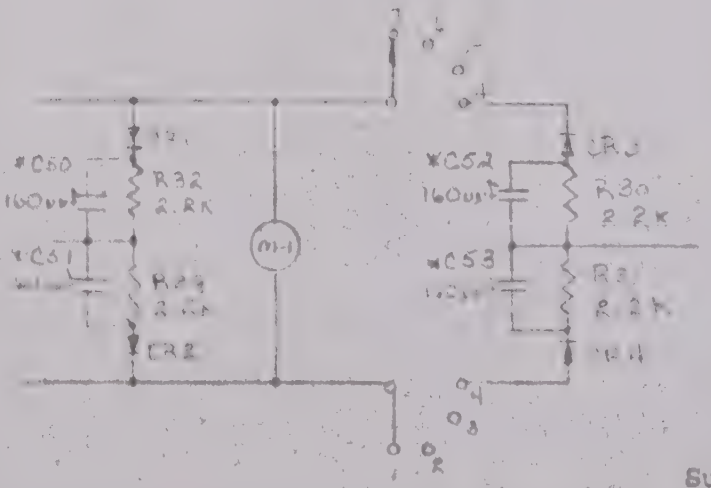
VM-202 MODIFICATION

In all instruments, Serial No. 6155 and higher, which have frequencies of operation above 2KC, the reference adjust potentiometer and the phase pot have been isolated from the chassis and have their cases driven. This is accomplished as shown in the following diagram:



NOTE: EXACT REDLINE REFERENCE IS REQUIRED FOR MAXIMUM ACCURACIES OF PHASE MEASUREMENTS.

* The capacitors indicated have been added to the demodulator section of the instrument as shown in the schematic below in all instruments Serial No. 6155 and higher.



Supplement #133
2-18-65

SECTION I

SPECIFICATION

General:

The NAI Phase Angle Voltmeter models covered by this specification are single frequency units in the range of 30 cps to 10 KC. The reference adjust knob on the front panel of the instrument and the nameplate identify the frequency of operation. These units are characterized as follows:

Model 202R	No Filter
Model 202AR	Filter in signal channel only
Model 202BR	Filters in signal and reference channel.

Note: The subscription "T" indicates that there is a built-in reference isolation transformer.

Additional optional features available include: Shielded Input Isolation Transformer, Rear Panel Connectors, and Custom Front Panels.

Voltage Range:

Full-Scale reading: 1 millivolt to 300 volts in 12 separate ranges.

Frequency Range:

Response for phase sensistive positions is at the indicated specific frequency of the reference (See Harmonic Rejection). For standard voltmeter operation response is from 10 cps to 50 KC when used on broadband. When used as frequency sensitive voltmeter, response is that of selective filters.

Frequency Response:

±2% 20 cps to 30 KC
±5% 10 cps to 50 KC

Accuracy at Frequency of Operation:

(a) Voltage: ±2% of full scale Voltage Range

(b) Angle: ±3% of full scale degrees as a phase angle meter using E cos θ characteristic, for up to 5:1 overload. (See page 9, Table II of Application Notes)

±1.0° using calibrated phase dial.

Phase Resolution:	.05° at 5 times full scale voltage (e.g., 5 volt input on 1 volt range)
Signal Input Impedance:	10 Megohms Resistive, Shunted by 40uufd capacity (when used with internal shielded isolation transformer for balanced input - 300K approximately at 400~ 1.0 meg. approximately at resonance).
Input D.C. Voltage Level:	D.C. levels may be applied without affecting performance, such that the peak value of the combined A.C. & D.C. voltages shall not exceed 1000V in the signal input and 600V in the reference input. (For direct input only - no D.C. shall be applied to optional isolation transformers.)
Reference Input Impedance:	100K nominal (25K above 2KC)
Reference Input Level:	.25 to 130 volts (1.25 volts minimum for units with reference isolation transformer.)
Common Mode Rejection:	(Instruments with signal isolation transformer.) Quad Output; zero source impedance, .0015% @ 400~, maximum output 1K source impedance, .0065% @ 400~, maximum output In-Phase Output; zero source impedance, .0002% @ 400~, maximum output 1K source impedance, .0005% @ 400~, maximum output
Reference Selector:	External reference at frequency of operation. One side grounded or isolated power line reference for 400 or 60~ power.

Meter and Dial Calibration:	Zero center voltmeters read RMS of Sine Wave. Line or voltage scales 3-0-3 and 10-0-10 reads E cos θ (angle between signal and reference as phase angle meter). Phase Angle Dial calibration 0° to 90° in 1° divisions. Four position Quadrant Selector.
Overload:	Overload alarm lamp set at 5X full scale voltage
Power:	115V or 230V ±10%, 60-400~. Approximately 60 watts at 60~. 115V fused @ 1.0A 230V fused @ .5A
Noise:	Less than 5 microvolts for low impedance input. Less than 50 microvolts for open input.
Nulling Sensitivity:	Less than 2 microvolts in phase sensitive mode.
Harmonic Rejection:	Greater than 55db with filters.

SECTION II

GENERAL DESCRIPTION

The VM-202 Series Phase Angle Voltmeter is a truly unique multi-functional instrument which will function as a:

1. Sensitive broadband vacuum tube voltmeter.

2. Phase angle voltmeter, at a rated frequency.
   i.e. Meter measuring in-phase signals
   (E cos θ), and quadrature signals
   (E sine θ)

3. Phase sensitive null indicator.

4. Impedance meter.

5. Power factor meter.

High input impedance (10 megohms) and voltage scale, ranging from .001 volts full scale to 300 volts full scale, make the instrument highly suitable for use on high impedance and low level circuits. Units with 10uv or 300uv full scale sensitivity are also available.

Power Line Voltages and Cable

The instrument is normally wired for use on 115 volts, 60-400 cps power (230V connection available). Power consumption is approximately 60 watts at 60 cps. A three conductor power cable with a polarized connector is supplied with the instrument when both signal and reference channel have built-in isolation transformers. All other instruments receive their chassis ground through either the signal or reference inputs.

CAUTION: TO AVOID THE PITFALLS OF GROUND LOOPS DUE TO MULTIPLE POINT GROUNDS, REFER TO THE SECTION IN THE APPLICATION NOTES (APPENDIX 2), TREATING THIS SUBJECT.

SECTION III

OPERATING INSTRUCTIONS

CONTROLS

On-Off

This toggle switch turns the instrument on as indicated by the power "ON" pilot light.

Range Switch

This switch selects the full scale voltage indicated at each position.

Terminals

The circuit ground terminals for both the reference and signal inputs are marked with a "G" and are colored black. The "Hi" sides of both inputs are colored red. These posts, which are on standard 3/4" spacing, will accommodate banana plugs, wire, or alligator clips.

CAUTION: MAXIMUM INPUT SIGNAL MUST NOT EXCEED 1000 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 600 VOLTS (COMBINED PEAK A. C. AND D.C. LEVELS). HIGHER VOLTAGES WILL DAMAGE THE INPUT CAPACITORS IN THE INSTRUMENT.

Function Selector

The "Function Selector" is used to select the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so as to read a voltage $E \cos \theta$, where θ is defined as the angle between the signal vector and the reference vector. The "Function Selector" then selects the quadrant over which the calibrated phase shifter will operate. Thus, the total angle shifted in degrees will be either 0°, 180°, or 270° plus the reading of the phase dial.

In the position marked "FUND", the instrument functions as a standard voltmeter and reads the total vector voltage of the fundamental signal.

In the position marked "TOTAL" (or just "STD VTVM" for the model 202R), the signal filter is removed, and the instrument functions as a standard voltmeter reading the entire input signal, including harmonics.

Reference Selector

This switch is used to select either an external reference or a line reference (for the case where the power line frequency is 60 cps or 400 cps and corresponds to the rated frequency.) In the position marked "ADJ." the reference is connected to the voltmeter and can be set to a reading from 1 to 10 on the 10 scale by using the knob marked "REF ADJ." The "Function Selector" should be in the "STD" position when making this adjustment. A red line is provided at mid-scale as a convenient point at which the reference level may be set.

NOTE: Phase measurements may be made with less than "Red Line Level Set." A minimum safe value, however, is a reading of 1 on the 10 scale. (See also Section I, "Specifications", Page 1.2, "Reference Input.")

The adjustment of level for the "LINE" reference has been made at the factory and corresponds to the red line condition. (60 cps and 400 cps instruments only.)

NOTE: Turnover of the line plug will shift the reference phase 180° when using the "LINE" reference.

Frequency/Phase Trim

This screw driver adjustment for R71 is located in the rear of the instrument and is used to re-zero the phase measuring dial as described under Phase Shifter Adjustment, Page 3.4.

DISPLAYS

Meter

The meter is a zero center d.c. milliameter calibrated to read the RMS value of a sine wave. For "STD VTVM" reading, the needle deflects to the right. For "PHASE ANGLE VOLTMETER" reading, the meter deflection may be either left or right.

CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE CAN OCCUR IF THE SIGNAL ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

Phase Angle Dial

This dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter with the particular quadrant selected by the "Function Selector." The actual calibration of this dial is non-linear. For this reason, should the dial ever be removed, the procedure under Phase Angle Dial Positioning of Section V should be followed when re-assembling.

Overload Lamp

The lamp marked "Overload" lights whenever the signal exceeds a prescribed level. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when large, saturating signals are present. The overload indicator is factory set at approximately five times full scale. Amplifier overload actually occurs at approximately ten times full scale.

FUSE

The fuse holder mounted on the back of the instrument contains a standard 1 amp. cartridge fuse. (.5 amp for 230V)

OPERATION

The instrument as received from the factory should indicate zero before being turned on. If it does not, reset the meter to read zero by means of the adjusting screw near the bottom of the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

With the instrument plugged into the proper power source, turn the toggle switch to "ON." Allow the instrument to warm up about 15 minutes for stable operation. For precision phase measurements, additional time should be allowed for the reference and signal filters to reach equilibrium temperature conditions.

The series 202 instruments are all characterized by being designed for single frequency measurements. The use of selective filters in conjunction with an R-C phase shifter results in a phase shift and amplitude characteristic which is a function of the frequency of the input signal. The filter characteristic is shown in Figure

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW SECTION ON GROUNDING TECHNIQUES IN APPLICATION NOTES.

To Measure Voltage

1. Set the "Range Switch" to the appropriate scale and the "Function Selector" to the "STD VTVM" position. The "Reference Selector" must be in either the "EXT REF" or "LINE REF" position.

2. Connect the voltage to be measured to the signal input terminal. Read the voltage from either the 0-10 scale or the 0-3 scale using the proper scale factor as determined by the "Range Selector" position.

   It will be notices that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to near zero.

   Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source. Care must also be taken to insure that ground loops do not exist by virtue of common signal and reference grounds which will result in erroneous readings.

To Measure Phase Angle

Reference Adjustment

1. With instrument turned on, connect the reference voltage to the reference input. The "Function Selector" should be in either "Fund" or "Total" positions.

2. Turn the "Reference Selector" to "ADJ" and adjust the "REF ADJ" knob until the meter reads on the red line. Return the "Reference Selector" to the "EXT." position. for all further measurements. (For less than red line, see "Reference Selector", Page 3.2

Phase Shifter Adjustment

1. This adjustment is factory set and should seldom need to be

touched except following servicing and tube replacement. Using a signal source equal to full scale on any range greater than 0.3 volts, connect the signal to both inputs and adjust the reference level in accordance with the preceding.

2. a) Place "Function Selector" in 0^{o} position and the "Phase Angle Dial" at 90^{o}. Place "Function Selector" in 90^{o} position and the "Phase Angle Dial" at 0^{o}.

   b) If the meter does not read zero for both these tests, use the back panel screw driver adjustment, R71, to provide a zero which is the best compromise for both cases. This control adjusts the phase shift between the signal and reference channels. In general, once this setting is made there is little reason to re-adjust the control unless special measurements are made such as, are described later in Section III, and in the appended Application Notes.

   The rezeroing of the R71 Frequency/Phase Trim will in no way affect the accuracy of the phase bridge adjustments.

Phase Angle Measurement Using Calibrated Phase Shifter

1. With reference adjusted to the red line and phase shifter properly zeroed, connect the input signal to the voltmeter and use the meter range providing a maximum on scale reading to the "STD VTVM" position.

2. Switch the "Function Selector" to a suitable "Phase Angle Voltmeter" position and turn the "Degrees Dial" to read a near maximum on the meter.

3. Switch the "Function Selector" an additional 90^{o}. Turn the "Degrees Dial" until the meter reads zero. Switch the "Function Selector" to a position (0^{o}, 90^{o}, 180^{o}, or 270^{o}), which gives a meter deflection to the right. The phase angle is then the sum of the "Function Selector" angle plus the "Phase Dial" angle. This rule eliminates the possibility of ambiguity.

Phase Angle Measurements Using E cos θ Characteristic

Accurate measurement of phase angle can also be made using the E cos θ or E sin θ characteristic. Voltage requirements are

made of the in-phase or quadrature component and of the fundamental signal (STD VTVM position). The ratio of the in-phase (or quadrature) to the fundamental, will equal the cosine (or sine) of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure and for that reason it is suggested the Application Notes be reviewed before using this method.

To Measure the In-Phase and Quadrature of a Signal

1. With the reference level set at redline, place "Function Selector" in 0^{o} position. Set the "Phase Shift Dial" at 0^{o}.

2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

3. Switch the "Function Selector" 90^{o}. The meter now reads the quadrature component or E sin θ. In general, one of these components is usually much smaller than the other, and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the overload lamp lights thereby warning of an impending overload condition. This light indicates that the total signal (combined in-phase and quadrature), in the amplifier, exceeds five (5) times the full scale value. Measurements can be made for overloads up to 10 times full scale at which time amplifier clipping takes place. Measurements under all these conditions will be most accurate if the zeroing process described in the Application Notes is followed.

DIFFERENTIAL MEASUREMENTS

In making differential measurements using a transformer, there are two sources of error. One is due to capacity from either side of the primary to the high side of the secondary as shown in Figure (**A**). This can result in an output even if $E_1 = E_2$. This effect is minimized if a secondary shield is used, connected as shown in Figure (**B**).

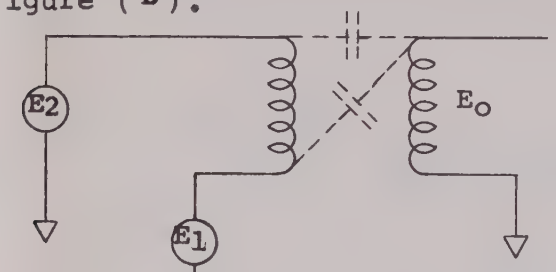


Fig. (**A**)

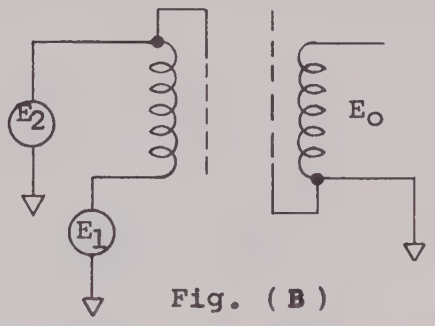


Fig. (**B**)

The other source of error is capacity to ground, phase shifting the signal from a source with a finite source impedance as shown in Figure (**C**).

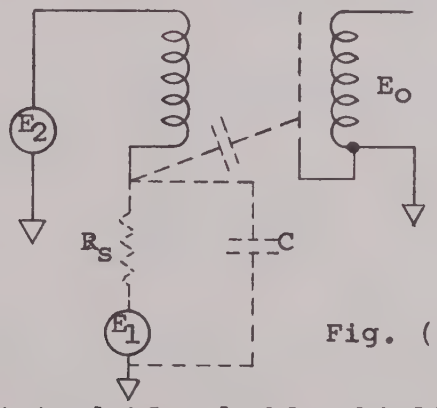


Fig. (**C**)

This effect is minimized if a double shielded wire and a primary shield is used as shown in Figure (**D**). This will connect the capacity from the inner conductor to the inner shield across the transformer which, when nulled, introduces no error. Capacity from the inner to outer shield and capacity from the primary shield to secondary shield is across E_2. If E_2 has a low source impedance, this will introduce no error.

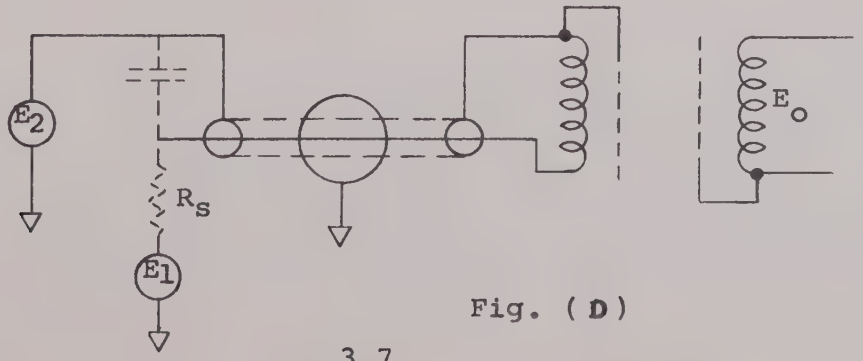
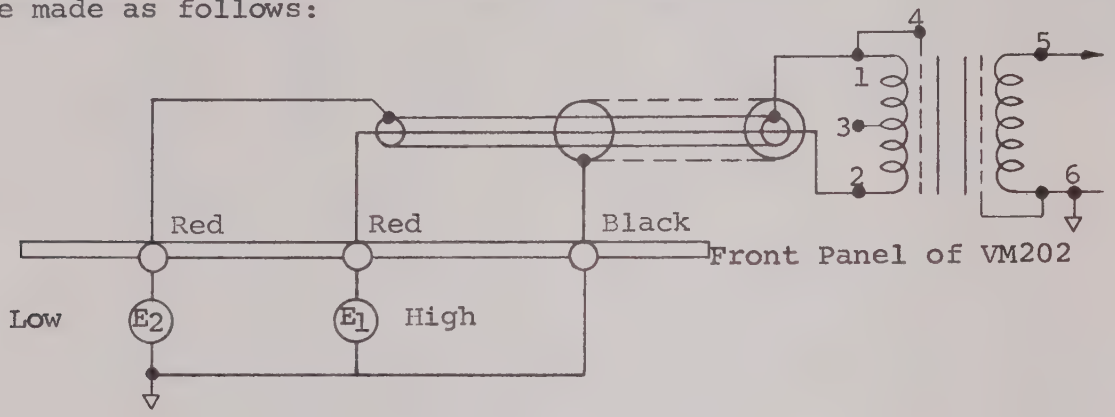


Fig. (**D**)

Therefore, for maximum accuracy in making differential measurements, the lowest impedance source should be connected to the No. (1) pin of the signal isolation transformer (available at the left hand red binding post of the signal input terminals). Connections should be made as follows:



Instruments which have rear M.S. connectors are wired as follows:

Pin A to Pin 1 of transformer
Pin B to Pin 2 of transformer
Pin C to ground

Input connections should be made as above.

SECTION IV

THEORY OF OPERATION

General

The block diagram of Figure 5.1 will serve to illustrate the principle of operation of the Phase Angle Voltmeter.

The input signal to be measured passes first to a high input impedance preamplifier, which contains the range multipliers and the signal filter (filter is switched out in STD VTVM position). For low level ranges (up to .3V full scale) the input signal is connected directly to the grid of V1. For the remaining ranges, the input range multiplier attenuates these signals by a factor of one thousand. The range multipliers are arranged so as to always provide a full scale voltage of approximately .001 volts at the input of V2.

The amplifier, consisting of V2 and V3, feeds the rectifier section of the voltmeter. This part of the circuit is arranged as a ring type demodulator (phase sensitive rectifier) when used as a Phase Angle Voltmeter or as a conventional full wave rectifier circuit where used as a conventional voltmeter. In both cases, heavy feedback is used around the silicon diodes and amplifier to minimize the non-linear forward characteristic of the diodes as well as the calibration shift normally associated with tube ageing.

The Reference Channel consists first of a potentiometer level control followed by a cathode follower V8. The cathode follower feeds into the reference filter which in turn goes directly into the first reference channel amplifier consisting of 1/2 of V4 and V5. This amplifier is a multi-loop feedback amplifier which provides a low impedance source for driving the second reference amplifier, which is identical to the first reference amplifier. The second amplifier then drives the phase sensitive rectifier when the instrument is used as a Phase Angle Voltmeter.

Amplifier

The main amplifier consists of an input pentode V2 driving a second pentode 1/2 of V3 which in turn drives the triode section of V3. Local feedback around the triode section serves to provide not only a very low output impedance, but additional stabilization for this stage, with only a slight reduction in overall loop gain. This latter is a result of the very high input impedance which the triode presents to the preceding pentode amplifier. Gain calibration for

the amplifier is accomplished by potentiometers R18 and R72. The output of the amplifier drives, in addition to the phase sensitive rectifier, an indicator I2 which is biased by means of R26 so as to light when the signal level exceeds five times the full scale meter reading. Thus, it is possible to measure very small out of phase signals in the presence of large non-indicating in-phase signals. Under special conditions, measurement with as much as 10 times full scale overload can be made. This type of overload will not damage the meter movement in any way.

Reference Channel

The Reference Channel gain is adjusted by means of level pot R33. With the "Reference Selector" set at the "ADJ" position, a small signal proportional to the reference level is derived from the cathode of V4 in the first reference amplifier and fed to the input of the signal amplifier. The level is then adjusted to read approximately half scale as indicated by the red line. For measurements involving a high ratio of out-of-phase to in-phase signal, it is frequently desirable to use an even greater reference level so as to minimize saturation effects in the phase sensitive rectifier itself. The scale allows an increase of 2:1 over the red line. Operation in excess of this level is not recommended except under special circumstances. The zero shift, which occurs when operating above the red line reference level, can easily be removed by using the Frequency Trim Control R-71 in the manner described in Section III.

Phase Sensitive Rectifier

The phase sensitive rectifier circuit is a conventional ring demodulator. Its operation can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through cathode resistor R18 and then the other end on the reverse cycle of the reference. The signal is therefore synchronously rectified through the meter movement. If the reference and signal are in phase, the average value will be a maximum, and the meter will read a maximum. If the signals are 90° apart, the average will be zero and no reading will result. The equation governing this is:

$$I_{meter\ (avg)} = K\ E \cos\theta$$

where K = proportionality constant
E = rms of signal
θ = angle between signal and reference.

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point ($\theta = 90^{o}$) are unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. All other frequencies are rejected except for signals very near to a response frequency. Here, the meter movement will oscillate between plus and minus maximums as the two near frequencies are alternately in-phase and 180^{o} out-of-phase. Response for this type detector to odd order harmonics will never be greater (usually less depending upon phase angle), than the fundmental response multiplied by a factor of 1/n where n is the order of the harmonic. Where a signal channel filter is used, there is, of course, essentially no response to harmonics in the signals.

The effect of reference harmonics is much less important than that of signal harmonics, because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed other wise, there is an equivalent error in degrees which results from harmonics in the reference channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using the E cos θ characteristic that effect is small, because the meter reading as a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

When used as a standard VTVM, the phase sensitive rectifier is switched to that of a full wave rectifier. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Phase Shifter

The Phase Shifter used is an RC type in which two half lattice sections are used to excite taps on a potentiometer. This type of device inherently has a non-linear change in phase shift for an input shaft rotation which results in the non-linear dial calibration used. The output of this device also varies in amplitude by a factor of 0.707. This variation causes substantially zero error in the instrument. In some instruments, trimming elements are used to improve the phase shifter linearity.

Filters

The filters used in the equipment are stabilized versions of the commercial filter having the same type number.

Power Supplies

The power supply furnishes a well filtered high voltage D.C. for all stages except V1 which uses, in addition, a voltage regulator. Filaments are all A.C. except for V1 and V2, which are supplied with a well filtered D.C. voltage from a bridge rectifier CR 5.

SECTION V

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. Detailed alignment procedures are described in Section VI. It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

Cover Removal

To remove top cover, remove six top screws. The bottom cover is taken off easily by removing the remaining eight bottom screws.

Tube Replacement:

CAUTION: DO NOT REMOVE TUBES FROM THE VOLTMETER WHEN POWER IS APPLIED.

No circuit in the VM-202 series is critical to tube replacement. However, for maximum accuracy the calibrations, as described in Section VI, should be checked following tube changing. In many cases, instrument malfunction may be traced to weak or faulty tubes. Before changing the setting of any of the internal adjustments, check the tubes.

Replacement of Parts

Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and re-adjustment may be required. Be careful to replace components as nearly as possible in the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires. (If, for any reason, the phase shift potentiometer, R51, must be replaced in instruments up to S/N4000, the "Phase Dial" must also be replaced. See replacement parts list, Page 5.3)

Replacement of Diodes

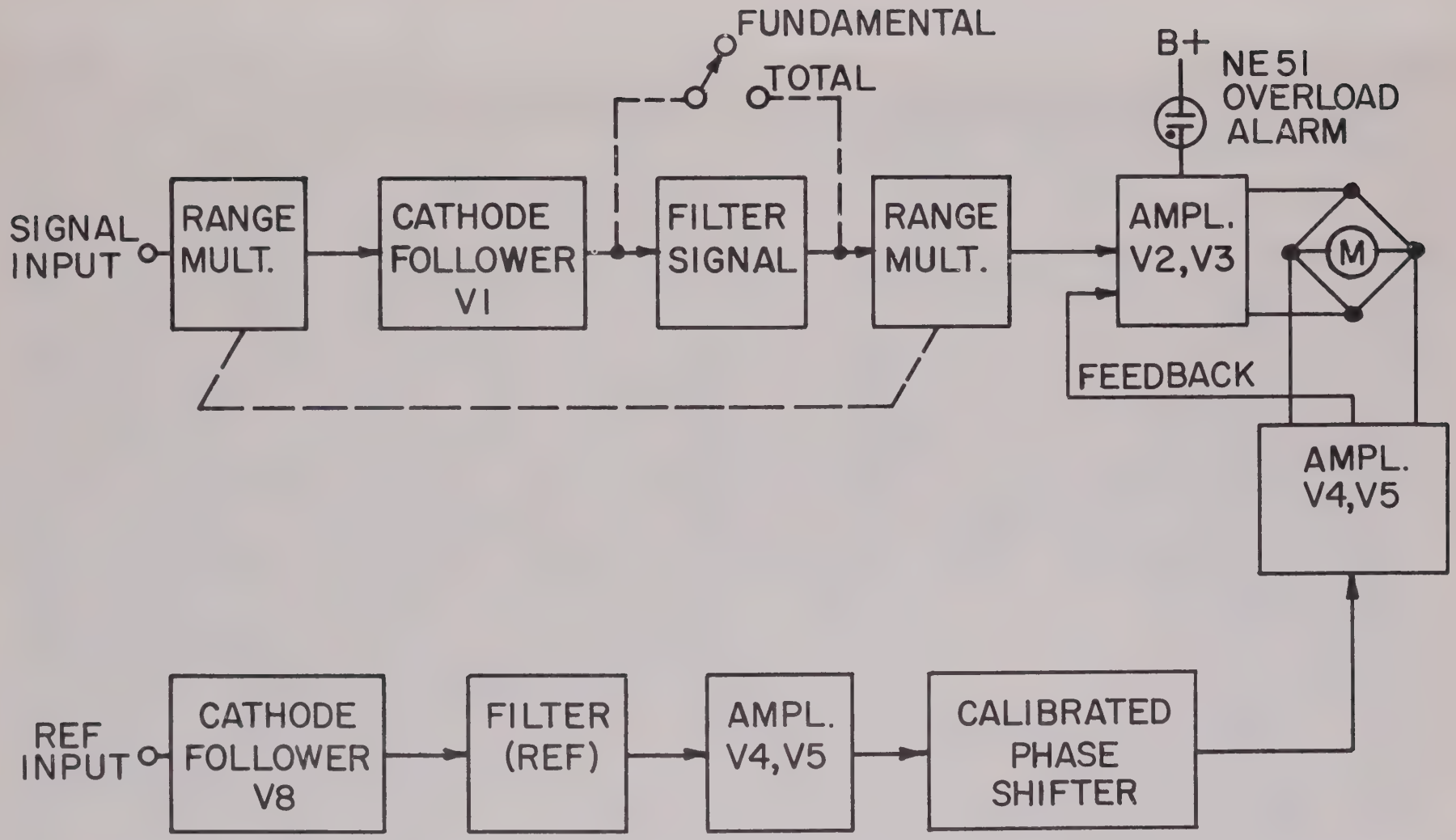
Four diodes are used in the voltmeter. Two are used in the voltage measuring circuits. All four are used in making phase measurements. If replacement of the diodes is required, be careful in soldering, as the heat may damage them. Place a heat sink on each diode lead as near to the body of diode as possible.

NOTE: If any of the diodes CR1, CR2, CR3, CR4, are replaced, the voltmeter calibration, frequency and phase adjustment should be checked and re-adjusted. (See Section VI.)

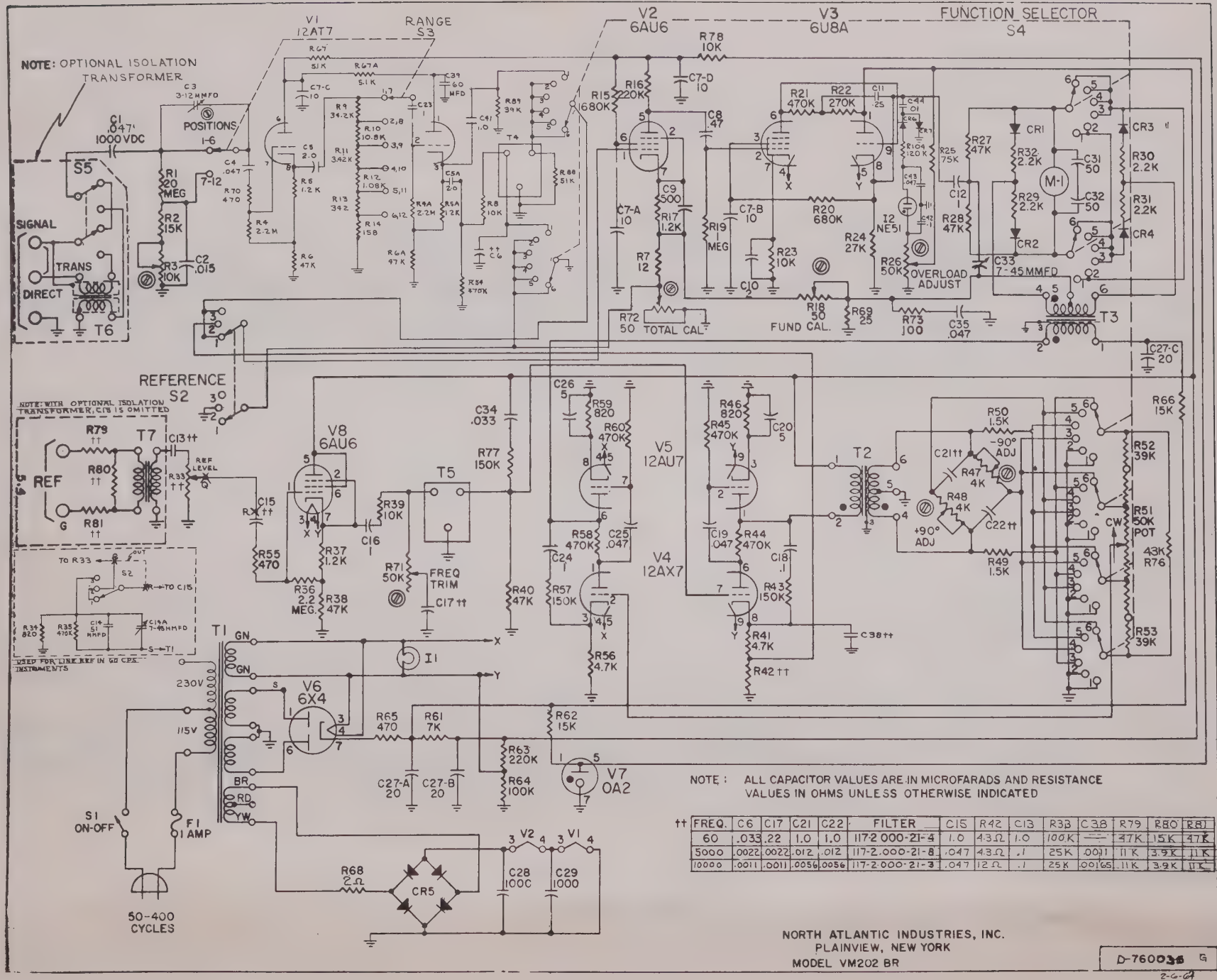
CAUTION: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazzard.

A potential shock hazzard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of instrument.

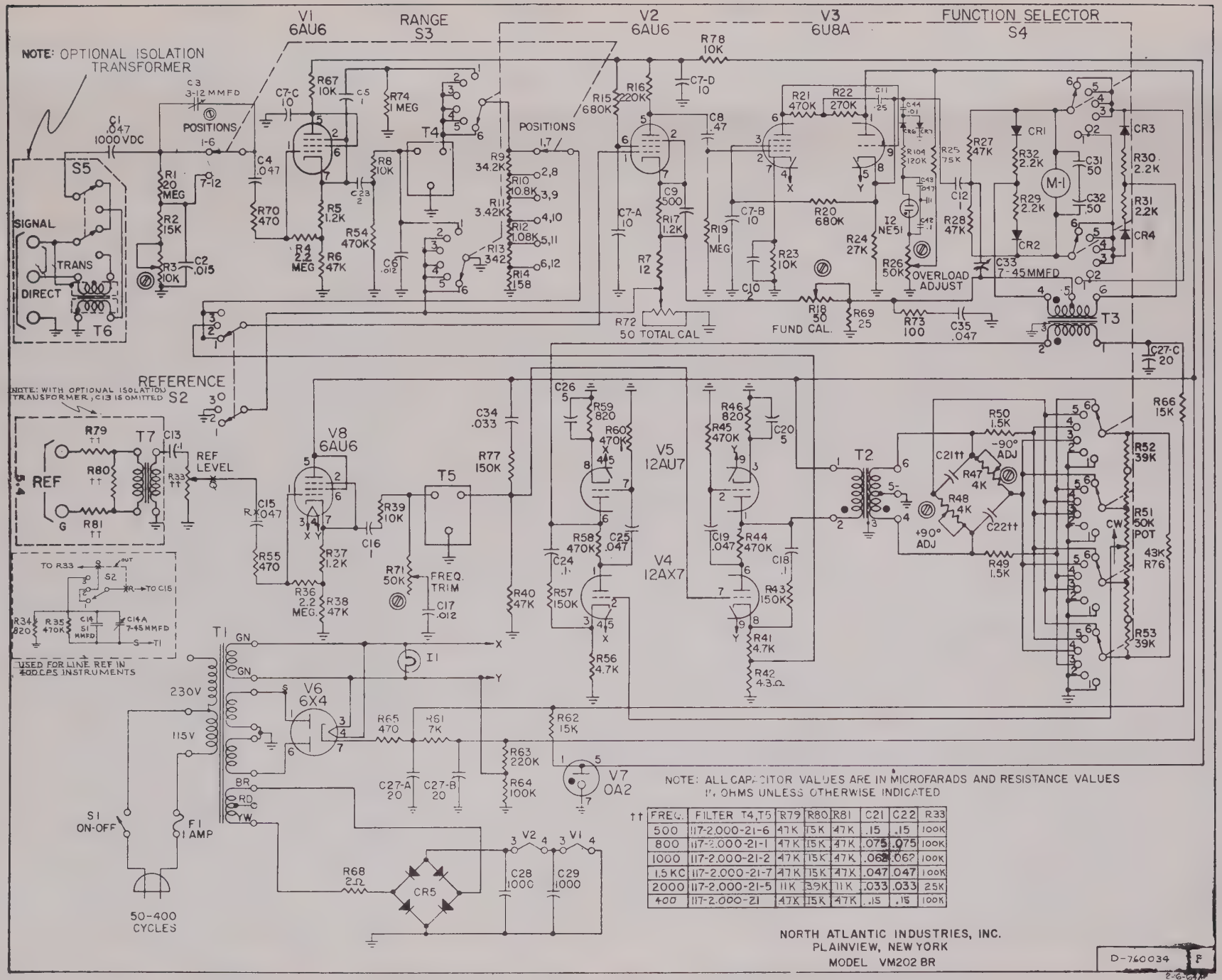


BLOCK DIAGRAM
VM 202BR
FIGURE 5.1



†† FREQ.	C6	C17	C21	C22	FILTER	C15	R42	C13	R33	C38	R79	R80	R81
60	.033	.22	1.0	1.0	117-2000-21-4	1.0	43Ω	1.0	100K	—	47K	15K	47K
5000	.0022	.0022	.012	.012	117-2.000-21-8	.047	43Ω	.1	25K	.0011	11K	3.9K	11K
10000	.0011	.0011	.0056	.0056	117-2.000-21-3	.047	12Ω	.1	25K	.00165	11K	3.9K	11K

Fig. 5.2A



††

FREQ.	FILTER T4,T5	R79	R80	R81	C21	C22	R33
500	117-2.000-21-6	47K	15K	47K	.15	.15	100K
800	117-2.000-21-1	47K	15K	47K	.075	.075	100K
1000	117-2.000-21-2	47K	15K	47K	.062	.062	100K
1.5 KC	117-2.000-21-7	47K	15K	47K	.047	.047	100K
2000	117-2.000-21-5	11K	3.9K	11K	.033	.033	25K
400	117-2.000-21	47K	15K	47K	.15	.15	100K

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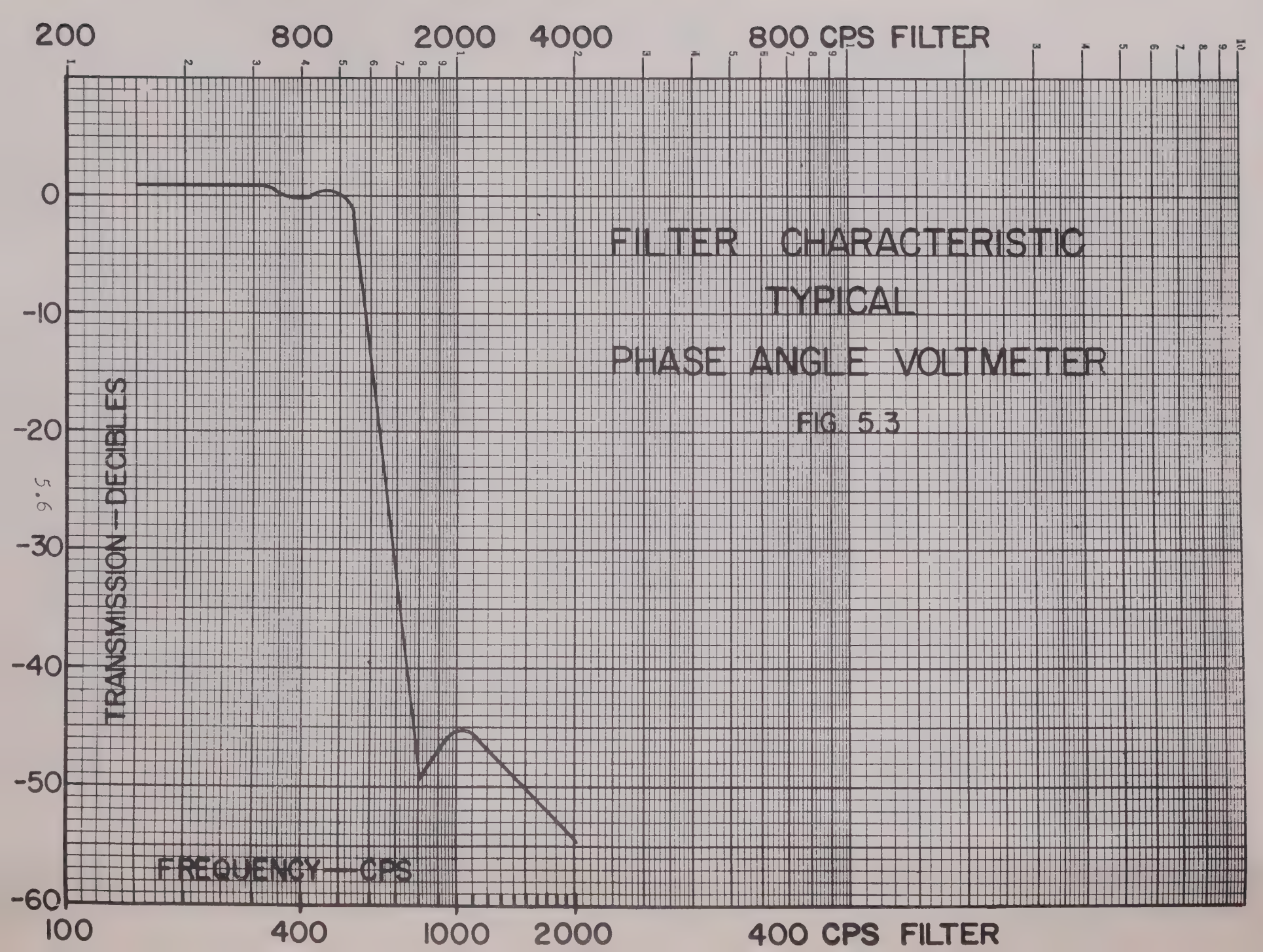
PLAINVIEW, NEW YORK
MODEL VM202 BR

D-760034 F

5*5

Fig. 5.2B


200
800
2000
4000
800 CPS FILTER
0
-10
-20
-30
-40
-50
-60
TRANSMISSION — DECIBLES
FREQUENCY — CPS
100
400
1000
2000
400 CPS FILTER
FILTER CHARACTERISTIC
TYPICAL
PHASE ANGLE VOLTMETER
FIG. 5.3
5.6

Replacement Parts List

North Atlantic Industries' Part No's are supplied for purposes of identification. Those parts marked * should be replaced only with exact replacements. All other parts may be replaced with any good grade commercial components of the same value.

Designation	Description	North Atlantic Part No.
C1	Capacitor, Paper, .047uf, 1000V D.C., Sprague 191P473010S4	NAI #800022
C2	Capacitor, Fixed, .015uf, 400V	NAI #800023
C6,C17	Capacitor, .012uf, 400V (See Frequency Table on Schematic)	NAI #801973
C3	Capacitor, Ceramic, Variable, 3-12uuf, Erie TS-B	NAI #800102
C4,C35	Capacitor, Paper, .047uf, 200V D.C., ±20%	NAI #800107
C5,C12,C16	Capacitor, Paper, 1.0uf, 200V D.C., ±20%	NAI #800026
C7 A,B,C,D	Capacitor, Electrolytic, 4x10uf, 450V D.C.	NAI #800014
C8	Capacitor, Paper, .47uf, 400V D.C., ± 20%	NAI #800025
C9	Capacitor, Electrolytic, 500uf, 6V D.C.	NAI #800100
C10	Capacitor, Electrolytic, 2uf, 50V D.C.	NAI #800099
C11	Capacitor, Paper, .25uf, 400V D.C., ±20%	NAI #800021
C13	Capacitor, .1uf, 600V (See Frequency Table on Schematic #760035)	NAI #800024
C14	Capacitor, Mica, 51uuf, 500V D. C.	NAI #801357
C15	Capacitor, Paper, .047uf, 200V D.C., ±20% (See Frequency Table on Schematic #760035)	NAI #800107
C18,C24	Capacitor, Paper, .1uf, 400V D.C., ±20%	NAI #800020
C19,C25	Capacitor, Paper, .047uf, 400V D.C., ±20%	NAI #800108

Designation	Description	North Atlantic Part No.
C20,C26	Capacitor, Electrolytic, 5uf, 50V	NAI #800098
C21,C22	See Frequency Table on Schematic	
C23	Capacitor, Metalized Paper, 2uf,200V D.C. ±20%	NAI #800017
C27 A,B,C	Capacitor, Electrolytic, 3x20uf, 450VD.C.	NAI #800013
C28,C29	Capacitor, Electrolytic, 1000uf,15V D.C.	NAI #800097
C31,C32	Capacitor, Electrolytic, 50uf, 6V D.C.	NAI #800106
C33,C14a*	Capacitor, Ceramic, Variable, 7-45uuf, Erie TS-E	NAI #800040
C34	Capacitor, Fixed, .033uf, 400V	NAI #800018
C42	Capacitor, Fixed, .1uf, 200V D.C.	NAI #802220
C43	Capacitor, Fixed, .047uf, 400V D.C.	NAI #802395
C44	Capacitor, Fixed, .01uf, 200V D.C.	NAI #802325
R1	Resistor, Fixed, 20 Meg., 1W, ±1%	NAI #802275
R2	Resistor, Fixed, 15K, 1/2W, ±1%	NAI #800066
R3	Resistor, Variable, WW, 10K, ±2W	NAI #800007
R4,R36	Resistor, Comp., 2.2 Meg., 1/2W, ±5%	NAI #800064
R5,R17,R37	Resistor, Comp., 1.2K, 1/2W, ±10%	NAI #800081
R6,R27,R28, R38,R40	Resistor, Comp., 47K, 1/2W, ±10%	NAI #800087
R7	Resistor, WW, 12 Ohms, 3W, ±5%, Dale RS-2	NAI #800074

Designation	Description	North Atlantic Part No.
R8,R23,R39, R67,R78	Resistor, Comp., 10K, 1/2W, ±10%	NAI #800089
R9	Resistor, Fixed, 34.19K, 1/8W, 1/4%	NAI #802401
R10	Resistor, Fixed, 10.8K, 1/8W, 1/4%	NAI #802402
R11	Resistor, Fixed, 3.4K, 1/8W, 1/4%	NAI #802403
R12	Resistor, Fixed, 1.081K, 1/8W, 1/4%	NAI #802404
R13	Resistor, Fixed, 341.9 Ohms, 1/8W, 1/4%	NAI #802405
R14	Resistor, 158.1 Ohms, 1/8W, 1/4%	NAI #802406
R15,R20	Resistor, Comp., 680K, 1/2W, ±10%	NAI #800061
R16,R63	Resistor, Comp., 220K, 1/2W, ±10%	NAI #800058
R18, R72	Resistor, Variable, WW, 50 Ohms, 2W	NAI #800010
R19,R74	Resistor, Comp., 1 Meg., 1/2W, ±10%	NAI #800063
R21,R35,R44, R45,R54,R58, R60	Resistor, Comp., 470K, 1/2W, ±10%	NAI #800060
R22	Resistor, Comp., 270K, 1/2W, ±10%	NAI #800059
R24	Resistor, Comp., 27K, 1W, ±10%	NAI #800826
R25	Resistor, Comp., 75K, 1/2W, ±5%	NAI #800090
R26	Resistor, Variable, Composition, 50k, 2W	NAI #800056
R29,R30,R31, R32	Resistor, Comp., 2.2K, 1/2W, ±5%	NAI #800079
R33	See Frequency Table on Schematic	

Designation	Description	North Atlantic Part No.
R34,R46,R59	Resistor, Comp., 820 Ohms, 1/2W, ±10%	NAI #800082
R41,R56	Resistor, Comp., 2.7K, 1/2W, ±10%	NAI #800078
R42**	Resistor, WW, 4.3 Ohms, 1/2W, ±5% (See Frequency Table on Schematic)	NAI #800076
R43,R57,R77	Resistor, Comp., 150K, 1/2W, ±10%	NAI #800057
R47,R48	Resistor, Variable, WW, 4K, 2W	NAI #800009
R49,R50	Resistor, 1.5K, 1/2W, ±10%	NAI #800080
R52,R53	Resistor, Dep. Carbon, 39K, 1/2W, ±10%	NAI #800067
R55,R70	Resistor, Comp., 470 Ohms, 1/2W, ±10%	NAI #800084
R61	Resistor, WW, 7K, 5W, ±5%	NAI #800016
R62,R66	Resistor, WW, 15K, 5W, ±5%	NAI #800015
R64	Resistor, Comp., 100K, 1/2W, ±10%	NAI #800086
R65	Resistor, Comp., 470 Ohms, 2W, ±10%	NAI #800083
R68**	Resistor, WW, 2.0 Ohms, 1W, ±5%	NAI #801767
R69**	Resistor, WW, 25 Ohms, 3W, ±5%, Dale RS-2	NAI #800075
R71	Resistor, WW, 50K, 2W, ±5%	NAI #800006
R73	Resistor, Comp., 100 Ohms, 1/2W, ±10%	NAI #800085
R104	Resistor, WW, 120K, 1/2W, ±5%	NAI #800869
R76	Resistor, Comp., 43K, 1/2W, ±5%	NAI #801024
V1,V2,V8	Tube, 6AU6	NAI #800031

** Nominal Value Only--Factory set for optimum performance.

Designation	Description	North Atlantic Part No.
V3	Tube, 6U8A	NAI #800028
V4	Tube, 12AX7	NAI #800029
V5	Tube, 12AU7	NAI #800032
V6	Tube, 6X4	NAI #800030
V7	Tube, 0A2	NAI #800033
CR1,CR2,CR3, CR4,CR6,CR7	Diode, IN658	NAI #801661
CR5*	Selenium Rectifier, Radio Recepter D16N1B1E1G	NAI #800055
M1	Meter	NAI #B117-2.010
XF1	Fuseholder, Littelfuse 342001	NAI #800117
F1	Fuse, 1A, Littelfuse 312001	NAI #800118
I1	Pilot Light, 6.3V, GE #44	NAI #800093
I2	Overload Lamp, NE51	NAI #800092
XI1	Lampholder, Pilot, Dialco 810B-112	NAI #800095
XI2	Lampholder, Overload, Dialco 810B-117	NAI #800096
	Binding Post, Black, Grayhill 2901B	NAI #800120
	Binding Post, Red, Grayhill 29-1R	NAI #800119
	Terminal Mount, Grayhill 29B11-1	NAI #800121
S4*	Function Switch Ass'y	NAI #500007
S2*	Reference Switch Ass'y	NAI #500005
S3*	Range Switch Ass'y	NAI #500006
S1	Switch, Toggle, C-H 8280 K15	NAI #800004
	Knob, Bar, Acton Labs KN-1P	NAI #800035

Designation	Description	North Atlantic Part No.
	Knob, Reference Adjust, Acton Labs KN-1	NAI #800036
	Line Cord	NAI #800115
T1*	Transformer, Power	NAI #C200874
T2,T3*	Transformer, Driver	NAI #800549
	*Phase Anggle Dial Assembly	
R51***	Resistor, Variable, 50K, WW, 2W,	NAI #B117-2.000-39

Modifications of the Replacement Parts List for the Schematic #760035 are as follows:

V1	Tube, 12AT7	NAI #801019
R67,R67A	Resistor, Comp., 5.1K, 1/2W, ±5%	NAI #800613
R4A	Resistor, Comp., 2.2 Meg., 1/2W, ±5%	NAI #800064
R5A	Resistor, Comp., 1.2K, 1/2W, ±10%	NAI #800081
R6A	Resistor, Comp., 47K, 1/2W, ±10%	NAI #800087
R88	Resistor, Comp., 51K, 1/2W, ±5%	NAI #800630
R89	Resistor, Comp., 39K, 1/2W, ±10%	NAI #801069
C23	Capacitor, Paper, .1ufd, 400V	NAI #800020
C5A	Capacitor, Paper, 2ufd, 200V	NAI #800017
C41	Capacitor, Paper, 1.0ufd, 200V	NAI #800026
C39	Capacitor, Electrolytic, 2 x 30ufd, 250V	NAI #801461

The standard replacement parts list preceding is for the VM202BR (filters in both channels). The following changes apply to the variations itemized.

VM202AR

North Atlantic Part No.

Deleted:

T5	Reference filter	
R77	Resistor, Comp., 150K, 1/2W, ±10%	
C34	Capacitor, paper, .033uf, 400V	

Changed:

R40	470 K, 1/2W, ±10%	NAI# 800060

VM202R

Deleted:

T4,T5	Signal and reference filters	
R77	Resistors, Comp.,150K, 1/2W, ±10%	
R72	Resistor, Variable, WW 50 ohms, 2W	
R74	Resistor, Comp., 1 Meg., 1/2W, ±10%	
R8	Resistor, Comp., 10K, 1/2W, ±10%	
R54	Resistor, Comp., 470K, 1/2W, ±10%	
C5	Capacitor, Paper, 1.0ufd, 200V ±20%	
C6	Capacitor, Paper, (See Schematic)	

Changed:

R40	Resistor, Comp., 470K, 1/2W, 10%	NAI# 800060
R7	Resistor, W.W., 25 ohms 3W, 5%	NAI# 800075
R42	Resistor, W.W., 5.6 ohms, 1/2W, 5%	NAI# 800317

C34 Capacitor, Paper, .047, 400V NAI# 800025

C34 is across R39

C23 connects directly to range switch at position 1-7, R9

Function switch section at T4 is deleted.

VM202- With built in-signal isolation:

Add:

*T6 Transformer, Signal isolation NAI#B117-2.000-30

C40 Capacitor, Mica, 470uufd, 300V NAI# 801971

VM202--T With built in Reference Isolation:

Delete

C13 Capacitor, Paper, (See Schematic)

C14 Capacitor, Mica, 51uufd, 500V

C14A Capacitor, Ceramic, Variable, 7-45uuf

Add:

*T7 Transformer, Isolation U.T.C. 0-6 NAI# 800050
*Shield, Transformer, UTC 0-17 NAI# 800051

R81, R79 Resistor, Comp., 47K, 1/2W, ±10% NAI# 800087

R80 Resistor, Comp., 15K, 1/2W, ±10% NAI# 800091

SECTION VI

CALIBRATION TEST PROCEDURE

CAUTION: Before proceeding with the Calibration Test Procedure, please take note of the following:

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazzard.

A potential shock hazzard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of instrument.

The adjustments described in this section require precision test equipment in order to achieve rated accuracy. If these are not available, it is recommended that the instrument be returned to the factory or submitted to a qualified instrument lab for recalibration.

I VOLTAGE CALIBRATION

A. Equipment Required

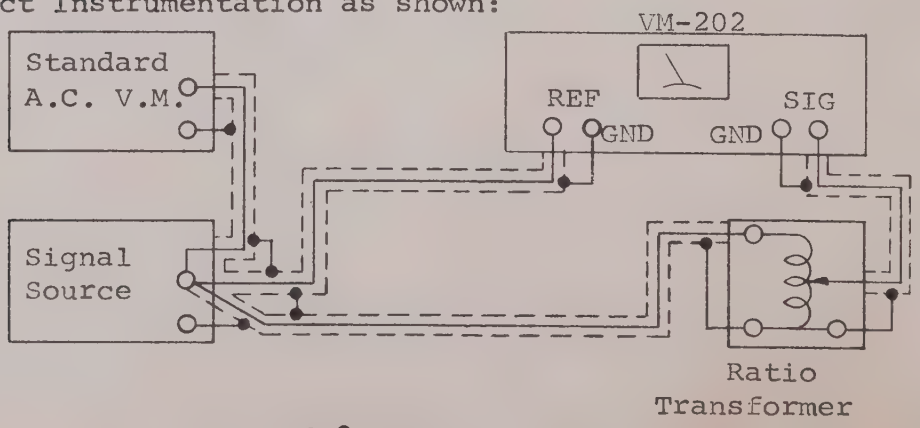
1. Variable voltage signal source capable of generating frequency of operation for the particular unit under test. Accuracy of frequency of the signal source should be ±1/2%. Output capability at least 20 volts, (e.g., Hewlett-Packard Model 200 CD).

2. Standard AC Voltmeter having accuracy of ±3/4% of full scale reading or better, (e.g., Poly Ranger Sensitive Research Corp. Model U-88).

3. North Atlantic Industries' Model RB-503 Ratio Transformer or equal.

CAUTION: DO NOT USE RESISTIVE DIVIDER, WHICH COULD INTRODUCE PHASE SHIFT

Connect Instrumentation as shown:



B. Procedure

1. Set output of frequency source to 10.00 volts as read on Standard Meter.

2. Set "Reference Selector" switch to "Adjust." Adjust Reference level to red line value.

3. Set "Reference Selector" to "EXT" and "Function Selector" to "FUND."

4. Set "Range Selector" to 0.1.

5. Set Ratio Transformer to 010000, (0.1 volts)

6. Adjust R18 (Fundamental Calibrate Pot located on top of chassis), until meter reads exactly full scale. Lock jam nut on R18.

7. Switch "Function Selector" to "TOTAL" and adjust R72 (total Calibrate Pot located on right side of chassis) for exactly full-scale reading. Lock jam nut on R72.

8. Set "Function Selector" to "0°" and turn "Phase Dial" until meter reads exactly zero.

9. a. Set "Range Switch" to 1.0

   b. Set Ratio Transformer to 300000, 3.0 volts out. (3x overload)

10. Adjust C3 (Trimmer Capacitor under input circuit shield on bottom of chassis, (Accessible through small hole in shield), until meter needle moves approximately half the number of scale divisions to zero.

11. a. Switch "Range Switch" to 3.0 volts.

    b. Switch "Function Selector" to "FUND" and adjust R3 (accessible through large hole in input shield, bottom of chassis), until meter pointer moves half the number of divisions between initial reading and full scale.

12. Repeat Steps 9, 10, and 11 until meter reads exactly zero when "Function Selector" is in "0°" position and exactly full scale when "Function Selector" is in "FUND" position.

Note: 1) There is considerable interaction between R3 and C3 and several adjustments may have to be made to set these controls to correct position. For frequencies above 1000 cps, the action of R3 and C3 is reversed, that is, R3 should be adjusted in Step 10 and C3 should be adjusted in Step 11. Lock R3 and glyptal C3 when this alignment is complete.

Note: 2) This test, as well asothers to follow, should be performed with meter in vertical plane.

II PHASE BRIDGE ALIGNMENT

Step B in the following procedure will align the "Phase Dial" to the pot, that is, the "0°" and "90°" points on the dial will be placed as close as possible to the taps on the pot.

Step C will be the phase alignment between the signal and reference channels. This consists of injecting a precise quadrature signal into the signal channel and an in-phase signal into the reference channel with the "Function Selector" and "Phase Dial" in the "0°" positions. The phase alignment is made by means of adjusting R71.

Step D will be the "squaring" of the Phase Bridge, that is, the precise adjustment of the "90°" and "270°" corners of the bridge.

A. Equipment Required

1. Variable voltage signal source capable of generating frequency of operation for particular unit under test (e.g., 60 cps, 400 cps, 800 cps, 1 KC, 10 KC, as applicable). Accuracy of the' frequency of the signal source should be ±1/2%. Output capability at least 20 volts (e.g., Hewlett-Packard Model 200 CD).

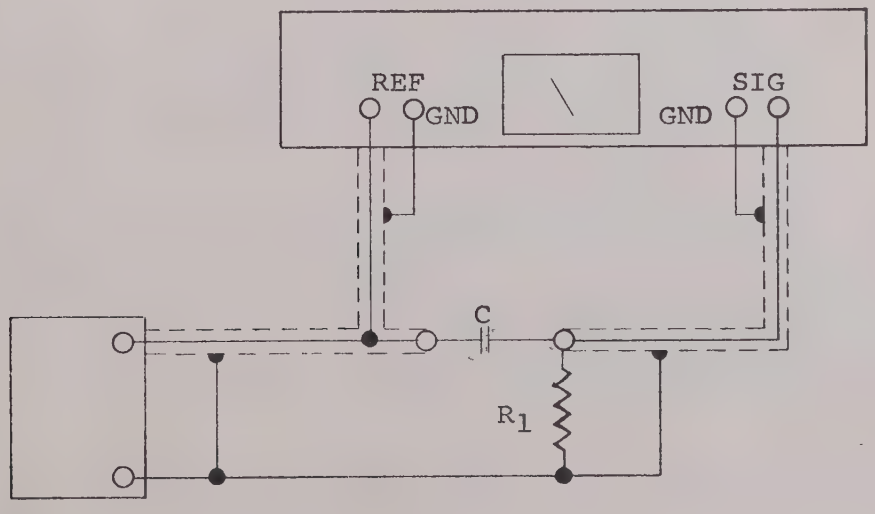
TABLE I

Operating Frequency	R_1 (Ohms)	C (MFD)	R_2 (Ohms)
60 cps	120	0.01	270,000
400 cps	180	0.001	390,000
800 cps	91	0.001	200,000
1,000 cps	91	0.001	160,000
1,500 cps	47	0.001	100,000
10,000 cps	91	0.0001	160,000

NOTE: The impedances of the above may be interpolated between frequencies shown.

CAUTION: R1, R2 should be stable type resistors such as Carbon film. C should be low loss type capacitor such as, polystyrene.

Remove the top cover of the instrument. Connect the signal source, capacitance, and resistor as shown in the block diagram below.



SIGNAL SOURCE
f ± 1/2%

B. Align "Phase Dial" on phase shifter pot R51 as follows:

1. Turn power off.

2. Set "Function Selector" to any phase sensitive position.

3. Use an ohmmeter to place the wiper of R51 exactly on the CCW tap point. Loosen dial clamping screw and rotate "Phase Dial" until dial reading is exactly 90°. Tighten clamping screw. Re-connect ohmmeter to CW tap point. Dial should now read 0°. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the 0° point reads low, the 90° point should read high by the same amount. Fully tighten knob set screw and recheck to make sure dial has not slipped during tightening.

4. Turn power on. Allow 30 minute warm up before proceeding with phase alignment.

C. Sig and Ref Channel Phase Alignment

1. Set "Function Selector" to "FUND."

2. Set "Reference Selector" to "EXT."

3. Set "Range Selector" to ".010."

4. Connect signal source to signal input terminals and adjust input voltage until a full scale reading on Phase Angle Voltmeter is obtained (10mv).

5. Turn "Reference Selector" to "ADJ" and adjust reference level for "red line" value on the meter scale. Return "Reference Selector" to "EXT."

6. Set "Phase Dial" to "0°."

7. Set "Function Selector" to "0°."

8. Set "Range Selector" to ".003." (approx. 3x overload)

9. Adjust R71 (back panel control) for zero reading on meter.

   NOTE: Signal and ref channel are now phase aligned. The 0^{o} "Function Selector" and "Phase Dial" position are now calibrated.

D. Phase Bridge Alignment

1. Remove capacitor and replace with R2, as noted in Table I above.

2. Set "Function Selector" to "FUND."

3. Set "Range Selector" to ".010."

4. Adjust voltage of signal source to give full scale reading on meter.

5. Turn "Reference Adjust" pot full counter clockwise.

6. Set "Reference Selector" to "ADJ."

7. Adjust reference to "red line" value.

8. Set "Reference Selector" to "EXT."

9. Set "Function Selector" to "90^{o}" and "Phase Dial" "0^{o}"

10. Set Range Selector" to ".003." (approx. 3x overload.)

11. Adjust R48 ($+90^{o}$ ADJ) until meter reads exactly zero.

12. Switch "Function Selector" to "0^{o}" and set "Phase Dial" to "90^{o}." Meter should read zero or very close to zero. If meter does not read zero, adjust R48 until offset from zero reading is the same for steps 11 and 12.

13. Set "Range Switch" to ".010." Set "Function Selector" to 180^{o} and "Phase Dial" to "90^{o}."

14. Set "Range Switch" to ".003." Adjust R47 (-90° adjust) until meter reads zero.

15. Set "Function Selector" to "270°" and "Phase Dial" to "0°." Meter should read zero or very close to zero. If meter does not read zero, adjust R47 until offset from zero reading is the same for Steps 14 and 15.

16. Repeat Step C.

17. Repeat Step D.

18. Repeat procedure of alignment (all steps) until no further adjustment of R71, R48, R47 will improve the zero reading of any of the steps.

NOTE: Misalignments from zero in terms of accuracy of ± 90° points can be calculated. Smallest division on meter is equivalent of 0.38° at 3:1 overload, e.g., 1 volt input and range selector on 0.3.

III FREQUENCY RESPONSE ADJUSTMENT

A. Equipment Required

1. Variable voltage frequency source capable of providing frequency of operation of instrument to 50,000 cps ±5% (e.g., Hewlett-Packard Model 200 CD).

2. VTVM having flat frequency response ±1% to 50 KC (e.g., Hewlett-Packard Model 400 D).

B. Procedure

1. Connect frequency source to signal input and monitor with VTVM.

2. Set frequency source to normal operating frequency of Phase Angle Voltmeter.

3. Set "Function Selector" to "TOTAL" position.

4. Set "Range Selector" to ".001."

5. Adjust voltage of frequency source until Phase Angle Voltmeter meter reads 9. Note reading of monitor VTVM.

6. Increase frequency to 50 KC and set voltage of frequency source until Monitor VTVM reads the same as reading noted in Step 5.

7. Adjust C33 (Trimmer Capacitor located on terminal board on bottom of chassis) until Phase Angle Voltmeter meter reads 9 minus 1/2 smallest division (approximately 1% full scale).

8. Repeat steps 4 through 6 on .003, .3, and 1.0 ranges and record Phase Angle Voltmeter readings. If necessary, re-adjust C33 to give vest overall tolerance on all ranges.

9. Acceptable performance will be an error of ±3% at 50 KC.

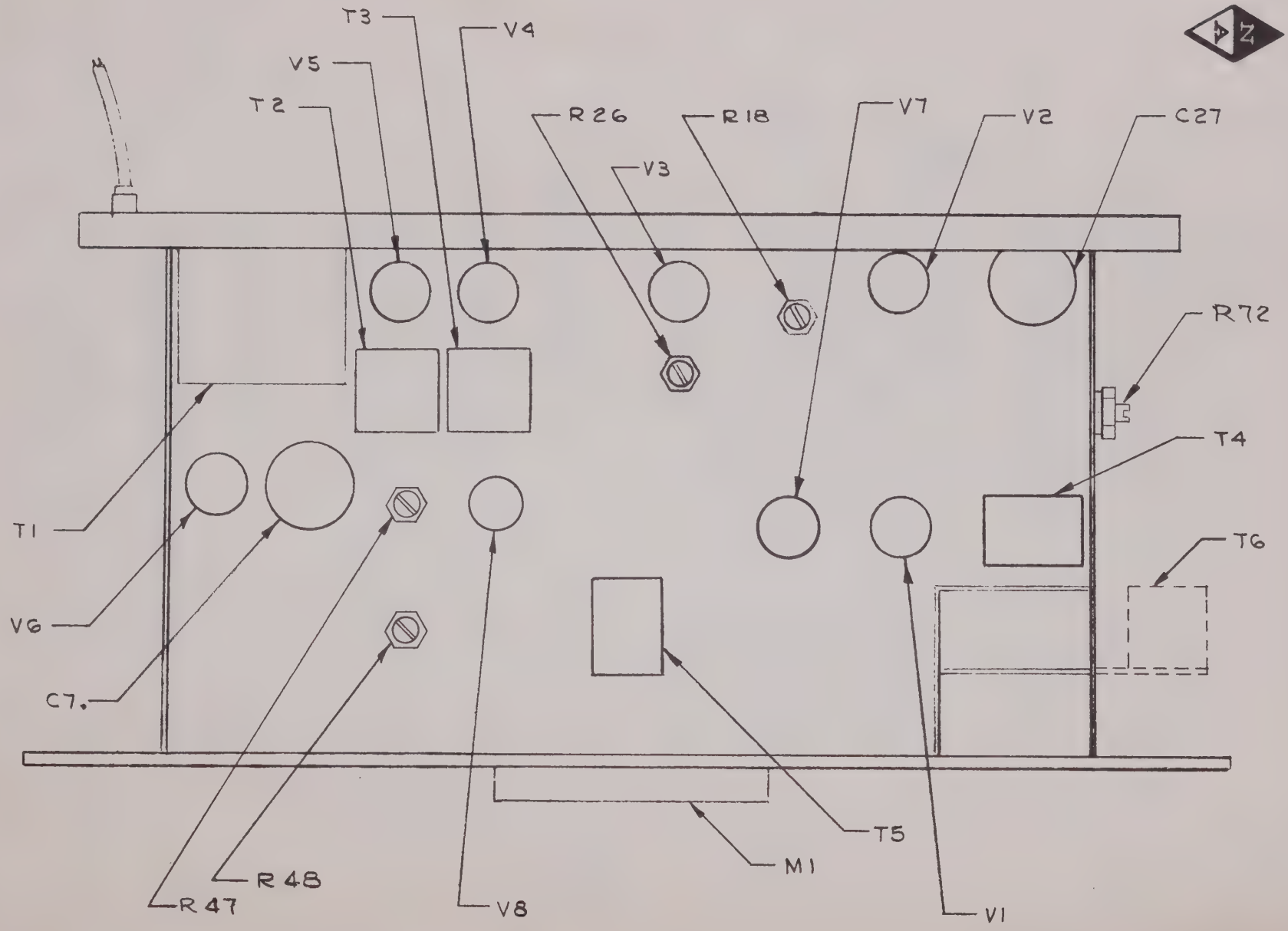
IV OVERLOAD ALARM ADJUSTMENT

This adjustment is usually required whenever the Ne-51 is replaced.*

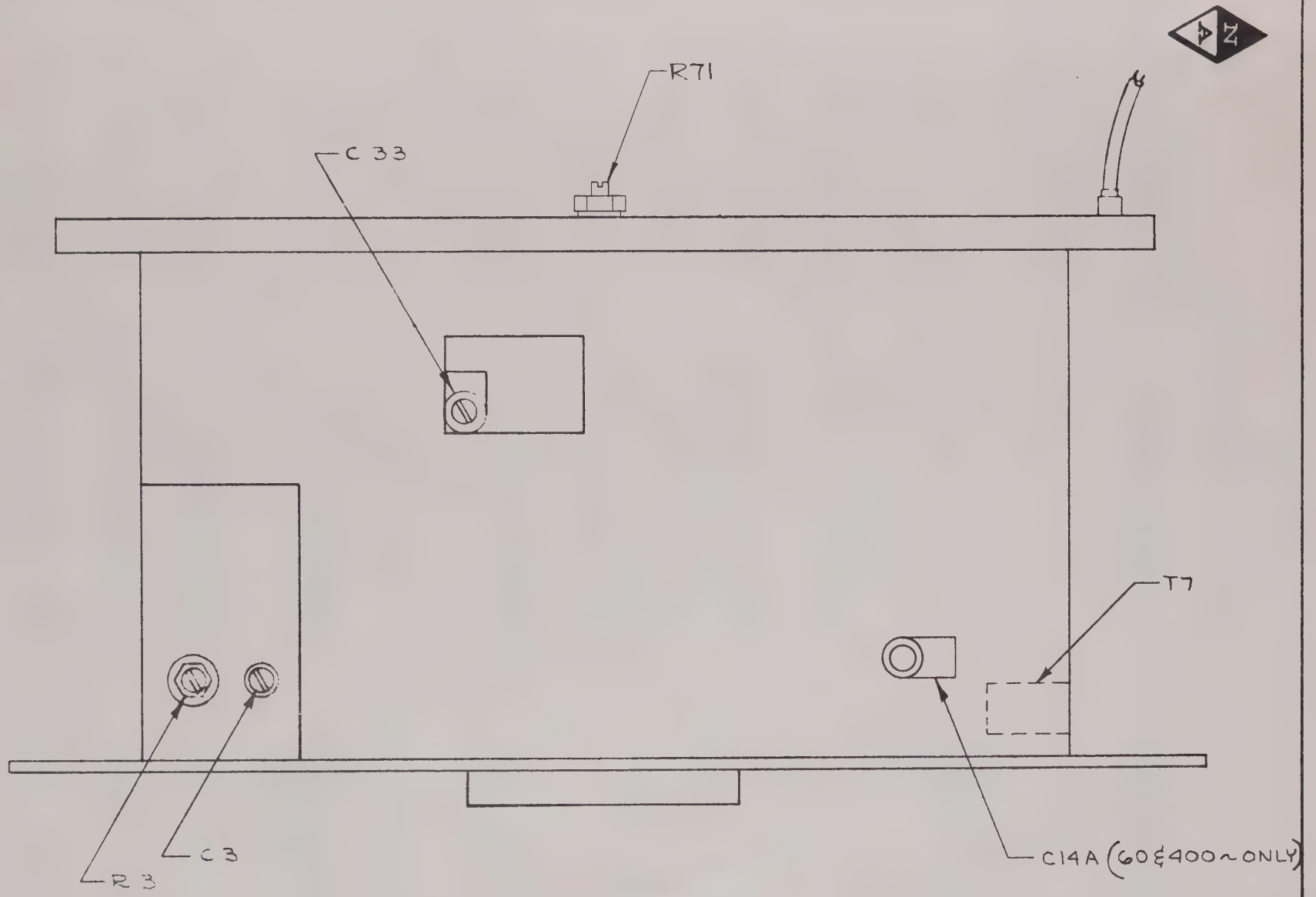
1. With an input of .5 volts applied to the instrument, switch the meter range to the 0.1 volt scale.

2. Adjust R26 until the overload lamp just lights.

CAUTION: Use only NE-51. Do not use NE-51H.



TOP VIEW
FIG. 6.1



BOTTOM VIEW
FIG. 6.2

SECTION VII

TROUBLE ANALYSIS CHARTS FOR VM 202

TROUBLE	PROBABLE CAUSE	REMEDY
Equipment fails to operate when turned on. Power lamp I1 does not glow. Filament of tube V3, V4, V5, V6, and/or V8 does not glow.	No power input.	Check power input at terminal 1 and 2, primary winding of power transformer T1.
	Fuse F1 defective	Replace fuse F1.
	Power lamp I1 defective	Replace power lamp I1.
	Tuve V3, V4, V5, V6, and/or V8 defective.	Replace defective tube(s).
	On-Off switch S1 defective	Replace On-Off Switch S1.
	Power Transformer T1 defective	Replace power transformer T1.
	Low (or no) filament voltage	Check for 6.3 volts AC at terminals 3 and 4, secondary winding of power transformer T1
Power lamp I1 glows. Filament of tube V1 and/or V2 does not glow.	Tube V1 and/or V2 defective	Replace defective tube(s).
	Bridge rectifier CR5 defective	Replace bridge rectifier CR5.
	Resistor R68 defective	Replace defective resistor
	Capacitor C28 defective	Replace capacitor C28

TROUBLE	PROBABLE CAUSE	REMEDY
Power lamp I1 glows. Filament of tube V1 does not glow, V2 does glow.	Tube V1 defective	Replace tube V1
	Capacitor C29 defective	Replace capacitor C29.
B+ voltage regulation at tubes V1 and V2. Voltage at capacitor C7D does not read 110 volts.	Tube V7 defective	Replace tube V7.
	Resistor R62 defective	Replace resistor R62.
	Capacitor C7 defective	Replace capacitor C7.
Overload lamp I2 does not glow with input signal of 5 times overload.	Low (or no) amplification from tube V1, V2, and/or V3.	Check voltage at junction of resistor R78 and capacitor C7D.
	Overload lamp I2 defective	Replace overload lamp I2.
	Capacitor C1, C2, C4, C5, C8, and/or C11 defective.	Replace defective capacitor(s).
	Potentiometer R26 defective	Replace potentiometer R26
	Filter T4 defective	Replace filter T4

TROUBLE	PROBABLE CAUSE	REMEDY
Meter M1 reads zero with input signal of 0.1 to 10 volts; voltage readings and tubes check satisfactorily.	Voltmeter M1 defective	Replace meter M1
	Capacitor C12 defective	Replace capacitor C12.
Voltage readings and tubes check satisfactorily; phase shifter alignment cannot be performed.	Potentiometer R51 defective	Replace potentiometer R51.
	Capacitor C21 and/or C22 defective.	Replace defective capacitor(s).
	Resistor R49 and/or R50 defective	Replace defective resistor(s).
	Transformer T2 defective.	Replace Transformer T2.
	Potentiometer R47 and/or R48 defective.	Replace defective potentiometer(s)
With input shorted slight tapping of instrument causes meter pointer to pin when Range switch S3 is set to 01.	Tube V1, V2, or V3 defective.	Replace tube V1, V2, or V3.

TROUBLE	PROBABLE CAUSE	REMEDY
Low (or no) reference level; voltage readings and tubes check satisfactorily.	Capacitor C18 defective.	Replace capacitor C18.
	Potentiometer R33 defective.	Replace potentiometer R33.
	Filter T5 defective	Replace filter T5
Instrument not phase sensitive. Reads to one side, all modes.	Diode CR1, CR2, CR3, and/or CR4 defective.	Replace defective diode(s).
	Potentiometer R51 defective	Replace potentiometer R51.
	Transformer T2 defective.	Replace transformer T2.
	Resistor R66 defective.	Replace resistor R66.
Instrument intermittent; noise level high with input shorted and FUNCTION switch set to FUND or TOTAL; AC Ripple levels erratic.	Power supply	Check power supply.
	Tube V1, V2, and/or V3 defective	Replace tube V1, V2, and/or V3.
Unable to adjust R71	Capacitor C6 defective	Replace capacitor C6
	Signal Filter defective	Replace signal filter
Unable to adjust R47 or R48	Capacitor C21 or C22 defective	Replace capacitor C21 or C22

SECTION VIII

VOLTAGE & RESISTANCE CHARTS

Phase Angle Voltmeters

MODELS 202

Voltage Readings

Item	Type	Pinl	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V1	6AU6	+43	+50	0	+6.0	+120	+120	+ 50	---	---
V2	6AU6	0	0	+12	+6.0	+ 53	+ 35	0	---	---
V3	6U8	+215	0	+52	0AC +71	6.3AC +71	+ 92	+2.5	+ 95	+ 95
V4	12AX7	+105	0	+1.1	0AC +71	0AC +71	+115	0	+1.1	6.3AC +71
V5	12AU7	+220	0	+ 7	6.3AC +71	6.3AC +71	+215	0	+21.5	+ 71
V6	6X4	0	0	+71	6.3AC +71	0	0	+370	---	---
V7	0A2	+150	0	---	0	+150	---	0	---	---
V8	6AU6	+ 83	+100	6.3AC +71	+ 71	+230	+230	+100	---	---

Resistance Readings

Item	Type	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 9
V1	6AU6	2.2m	47K	---	---	125K	125K	47K	---	---
V2	6AU6	500	1.2K	---	---	300K	800K	1.2Ω	---	---
V3	6U8A	75K	1.2K	700K	---	---	750K	10K	28K	800K
V4	12AX7	550K	11Ω	5K	---	---	550K	45K	75K	---
V5	12AU7	90K	500K	900Ω	---	---	100K	470K	900Ω	---
V6	6X4	270Ω	---	---	---	---	280Ω	85K	---	---
V7	0A2	95K	0	---	0	95K	---	0	---	---
V8	6AU6	2.4m	4.8K	---	---	75K	75K	48K	---	---

Resistance measured from output of filters to ground (T1 & T5) 45k.

Reference Transformers

Item	Pin 1		Pin 2		Pin 4		Pin 5	
+2	100k	+230	100k	+220	60Ω	0	60Ω	0
+3	110k	+225	110k	+215	75Ω	0	75Ω	0

Note:

All readings taken with VTVM input resistance 10 meg. All readings are made to ground. Function Switch in Total position, Range Switch in .1 volt position, Reference Switch in EXT position, Reference and Signal inputs shorted. All Voltages and Resistance ± 20%.

WARRANTY

North Atlantic Industries, Inc. warrants its products against defects in material and workmanship for one year from the date of the original shipment. Our liability is limited to repairing or replacing products (except fuses and electron tubes) which prove to be defective during the warranty period.

North Atlantic Industries, Inc. is not liable for consequential damages or for any damage or injury to persons or property resulting from the operation or application of any of its equipment.

Warranty is voided if there is evidence that the product has been operated beyond its design range, improperly maintained, or physically mistreated.

In the event of a malfunction in a product under warranty, the purchaser should notify his local Sales Representative or the Sales Department of North Atlantic Industries, Inc. giving full details of the defect and providing the model and serial number of the instrument. Service data or shipping instructions will be forwarded promptly. There is no charge for warranty repair of products, except transportation charges.

North Atlantic Industries, Inc. reserves the right to make changes and improvements in its products without any liability for incorporating such changes or improvements in any products previously sold.

No other warranty expressed or implied is offered other than the foregoing.

Estimates of charges for out of warranty repairs or other service work will be supplied before work begins. Out of warranty repairs will only be made following the receipt of purchaser's authorization of applicable charges.

Claims for Damage in Shipment

The purchaser should inspect and functionally test the product in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

(turn over for Shipping Instructions)

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. OVerbrook 1-8600

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On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

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Please complete and mail this Warranty Registration Card without delay. Placing this Registration on file with our Service Department will assure that you receive applicable service data as issued. No postage is required.
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SERVICE INFORMATION

This card is provided to aid you in obtaining prompt assistance with questions you may have regarding operation, calibration, maintenance or service parts for your North Atlantic instrument. State information desired and mail. No postage is required.

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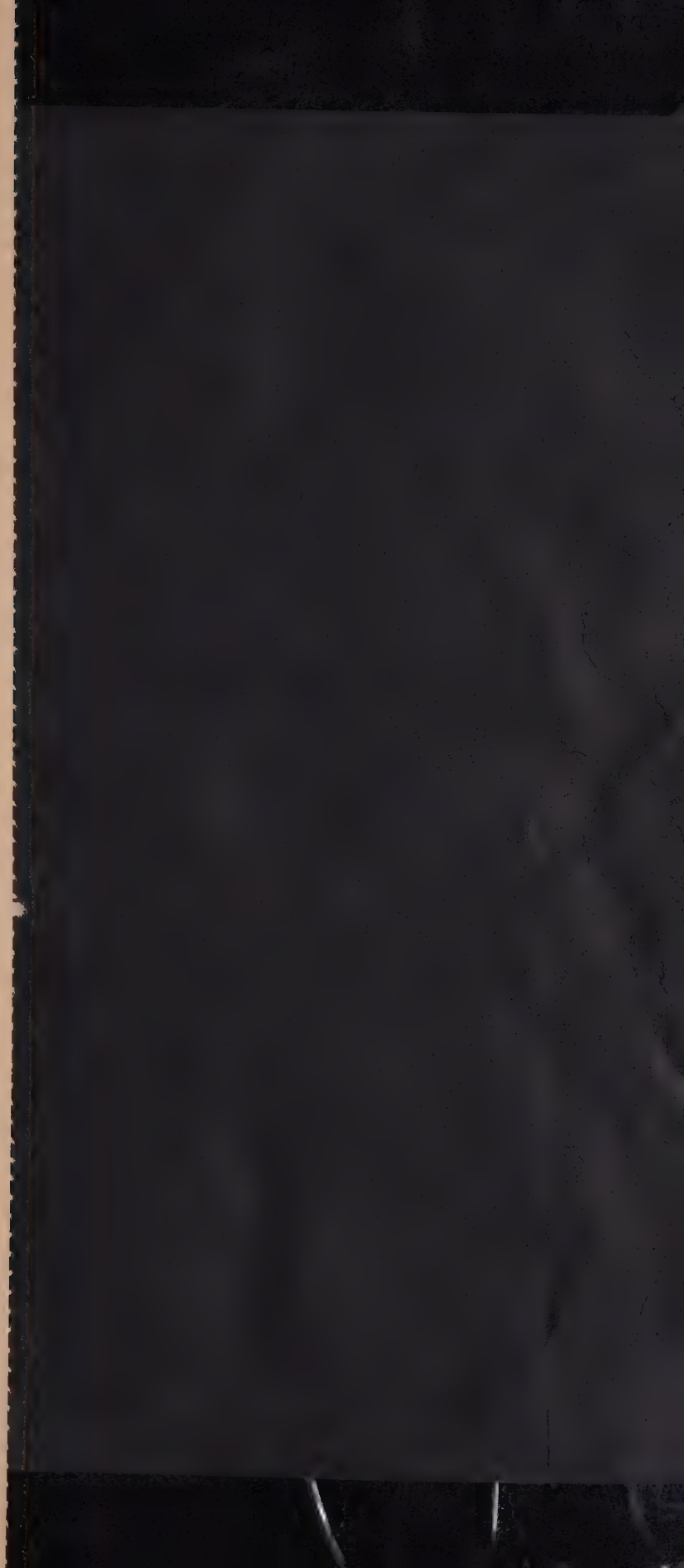
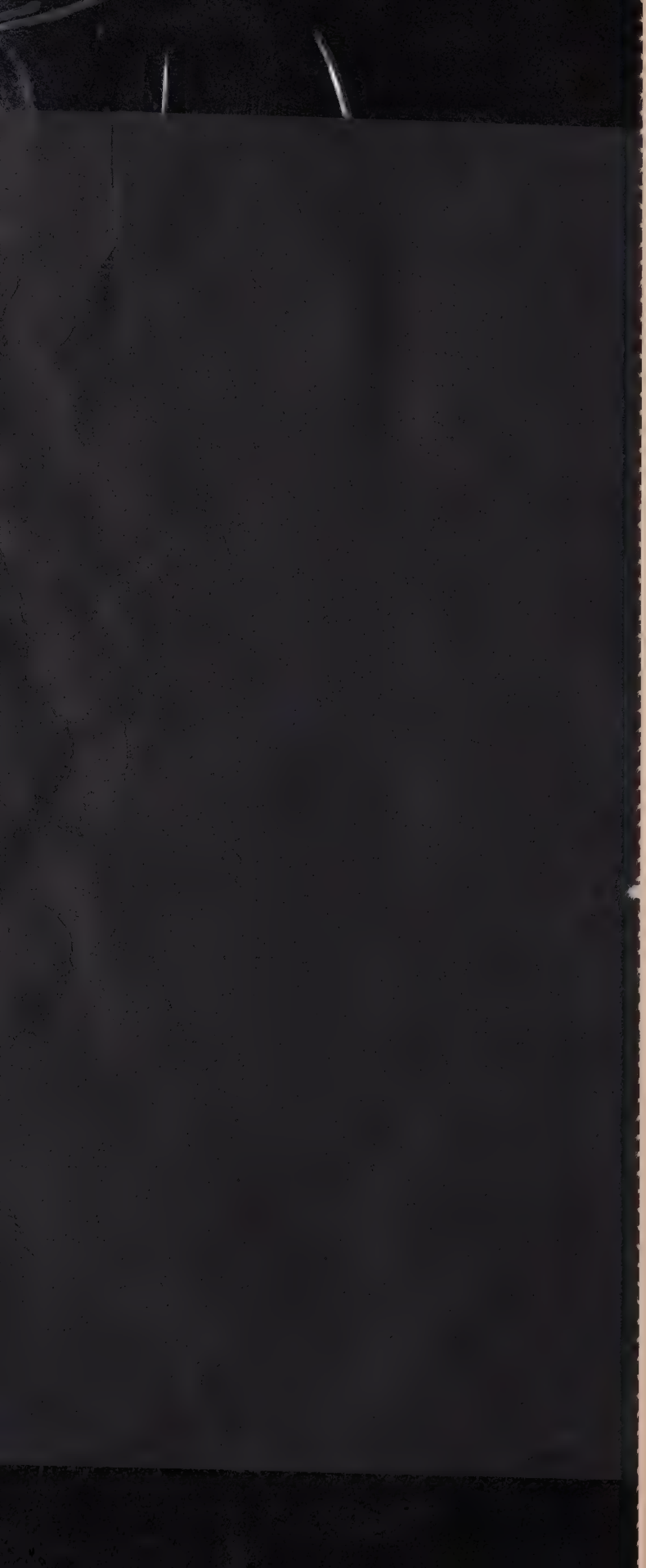




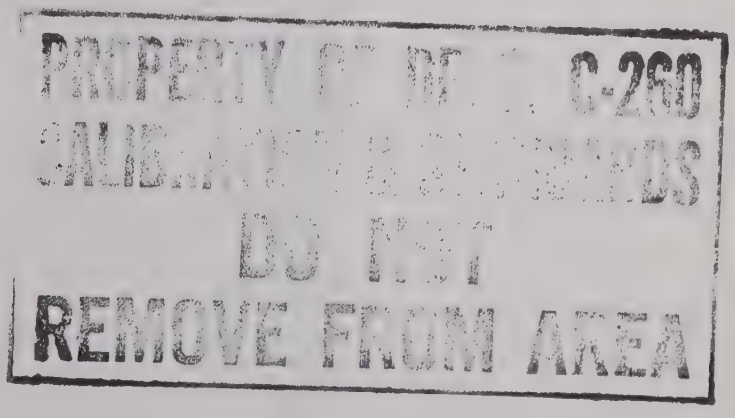
APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter and a power factor meter.



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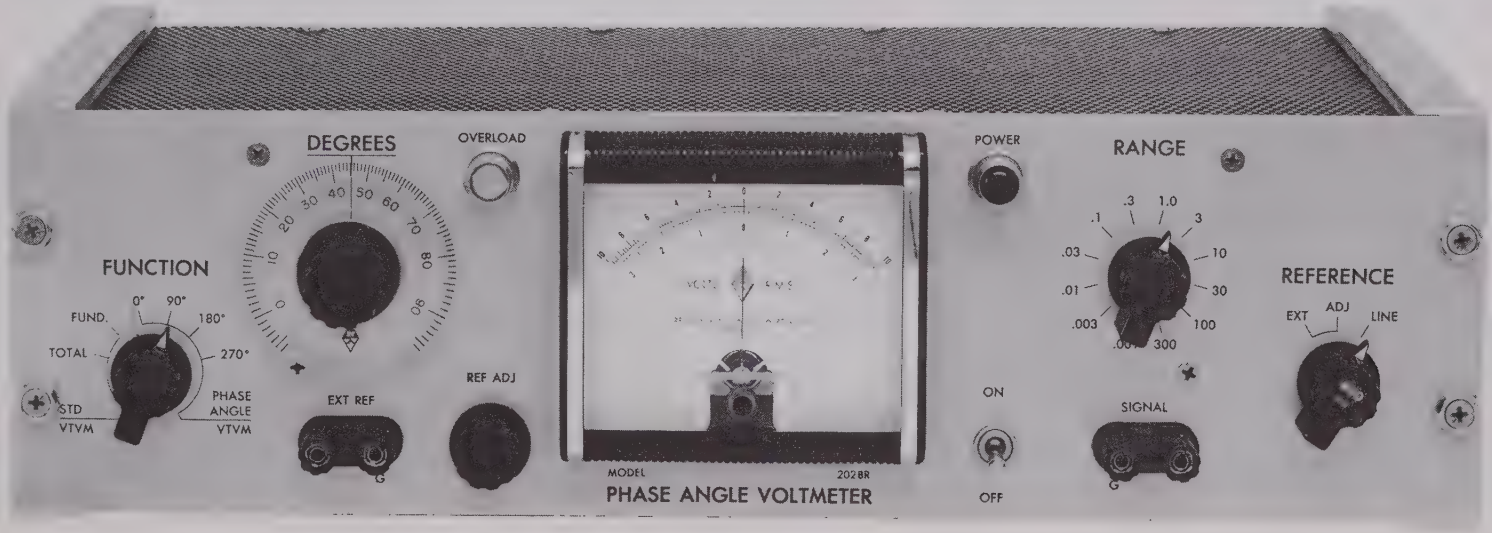

PHASE ANGLE VOLTMETER

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I-INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instruments ability to measure the two basic characteristics of any signal, namely magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure 1.

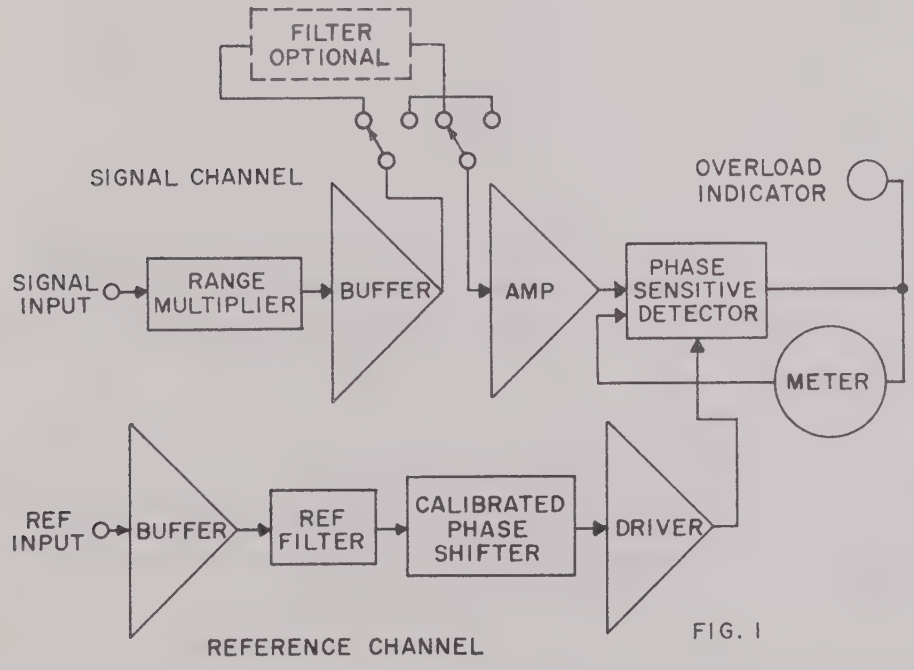


FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an a.c. signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures 5 and 6.

The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II-GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

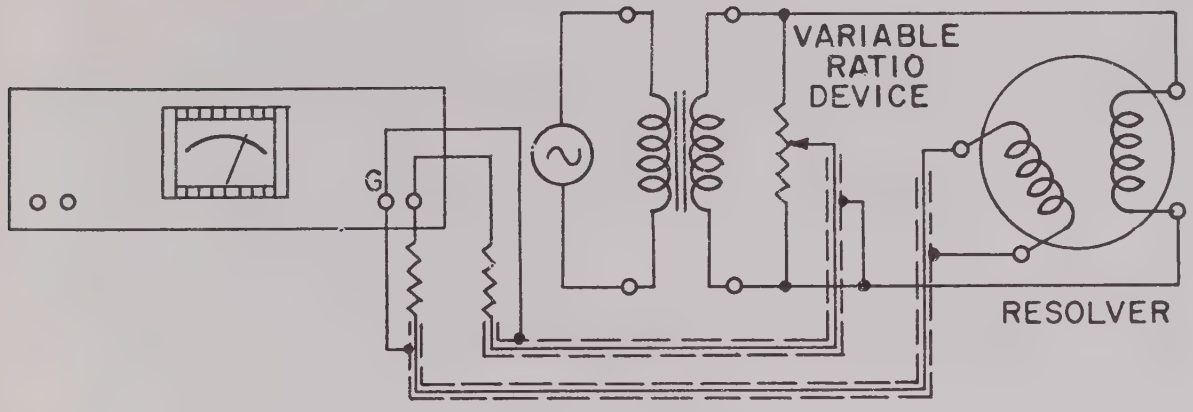
(a) Internal noise
(b) Electrostatic pickup
(c) Inductive pickup
(d) Common Ground Runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

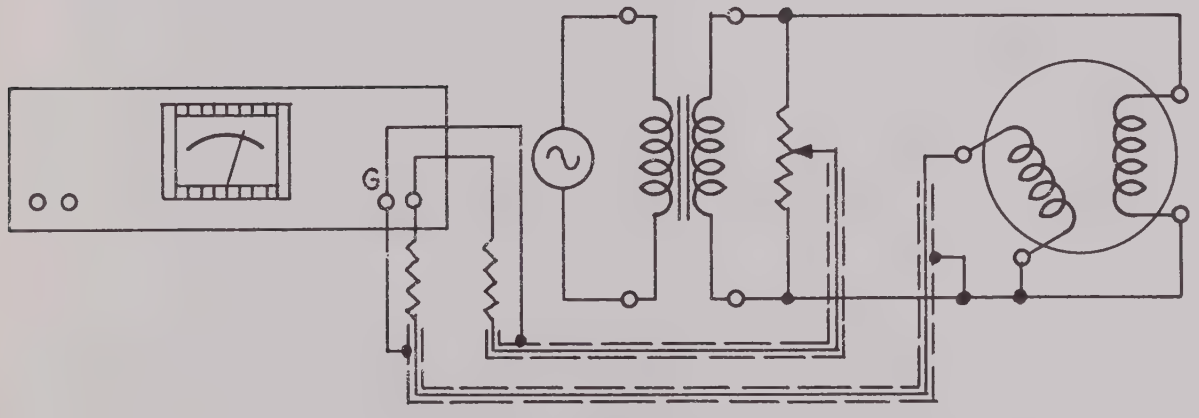
Electrostatic pickup, frequently a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads, one of which is at ground potential. Care must be taken however to avoid loading the signal source by the by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pick-up and possibly for that reason methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

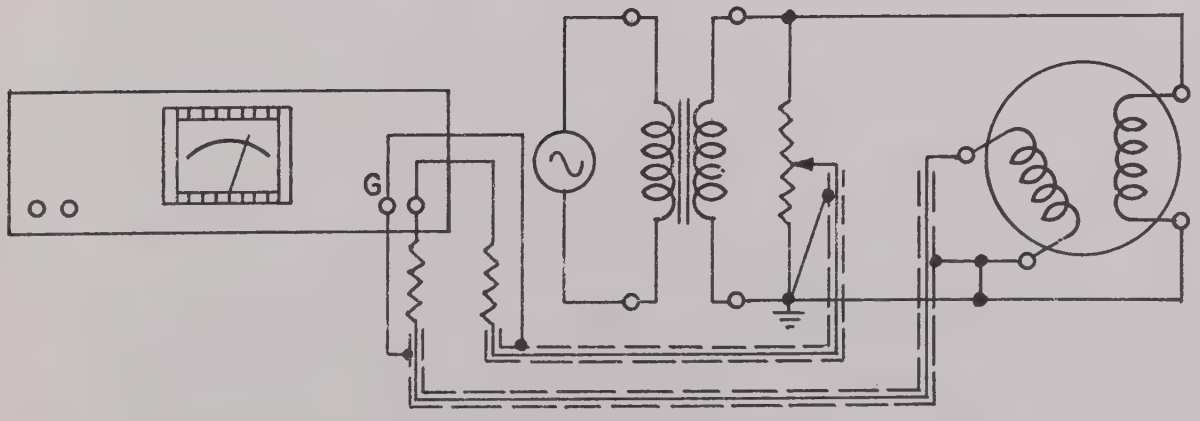
Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that portion of a circuit where a measurement is being made. Fig. 2 shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure 2A is the most advantageous arrangement and is not at all critical to lead runs. Figures 2B and 2C both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure 2 can exist due to chassis contact, line cord ground and reference grounds. All must be considered when setting up the measuring system.



(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

Common Ground Runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure 3 is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure 3 also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

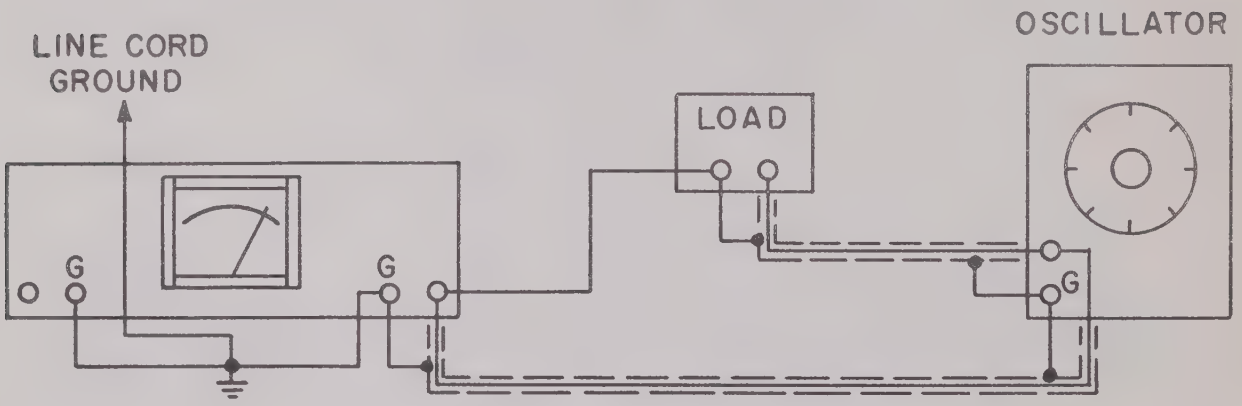


FIG. 3

III-PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter

E_{rms} = rms value of the input sine wave

θ = angle between the reference and signal input (phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

$$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55 db down. Table I shows typical measured responses. The values shown with filters actually are the sum of the column I data and the filter characteristic.

TABLE I

	RESPONSE SIGNAL	
	No Signal Filter	With Signal Filter
FUND (400 cps)	0 db	0 db
2nd Har	-55 db	> -55 db
3rd Har	-9.5 db	> -55 db
4th Har	-55 db	> -55 db
5th Har	-14 db	> -55 db

Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the set-up shown in Figure 4. The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement then will be a voltage which can be directly translated into degrees using the curves of Figures 5 and 6.

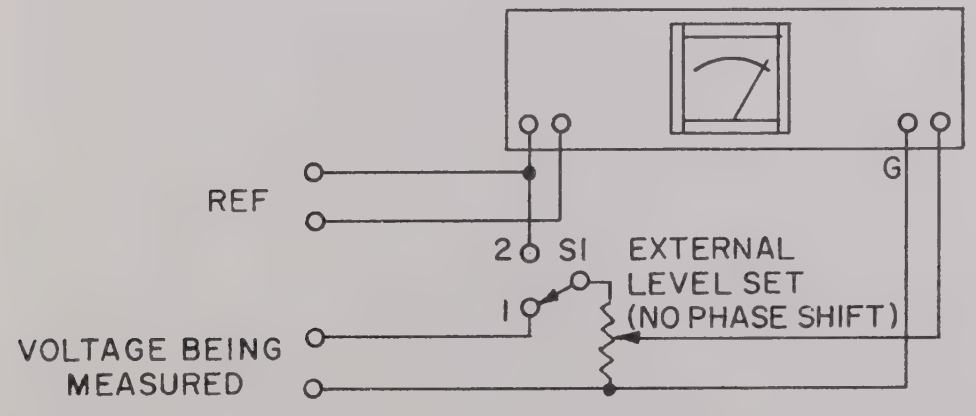


FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (Note: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.

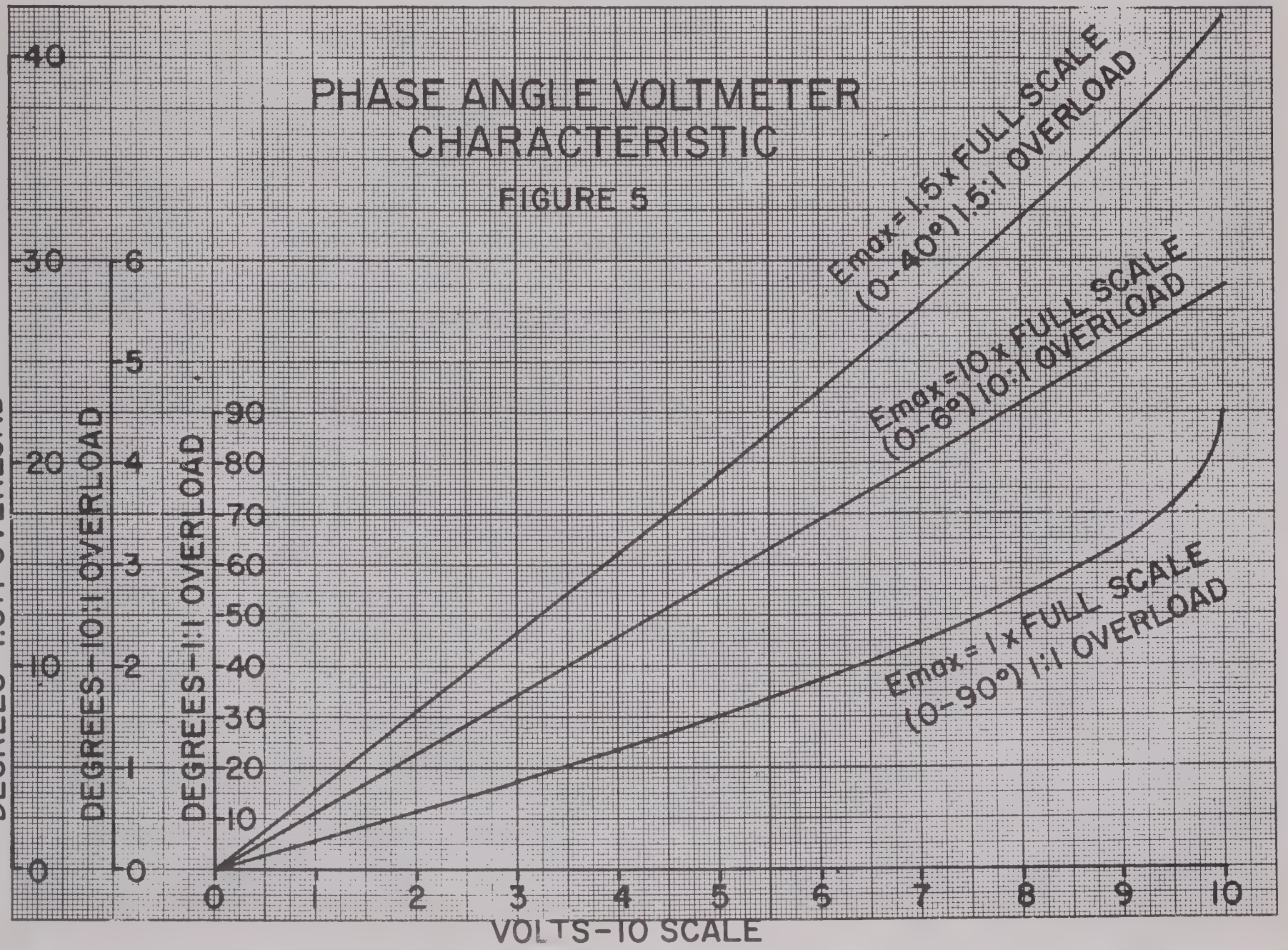
3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection. Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the $\theta = 0$ deg. point or quadrature null point. NOTE: FOR MAXIMUM ACCURACY THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the $\theta = 90$ deg. point. (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure 5 or 6 to read degrees.

Any full scale range in degrees can be used even down to -6°-0-$+6^{\circ}$ depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4 deg.-0- +17.4 deg. Table II summarizes typical set-ups and Figures 5 and 6 show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously this condition is a function of reference level and for that reason a level of twice the red line value is recommended when using this techique.


PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5 x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10 x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1 x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
50
70
80
90

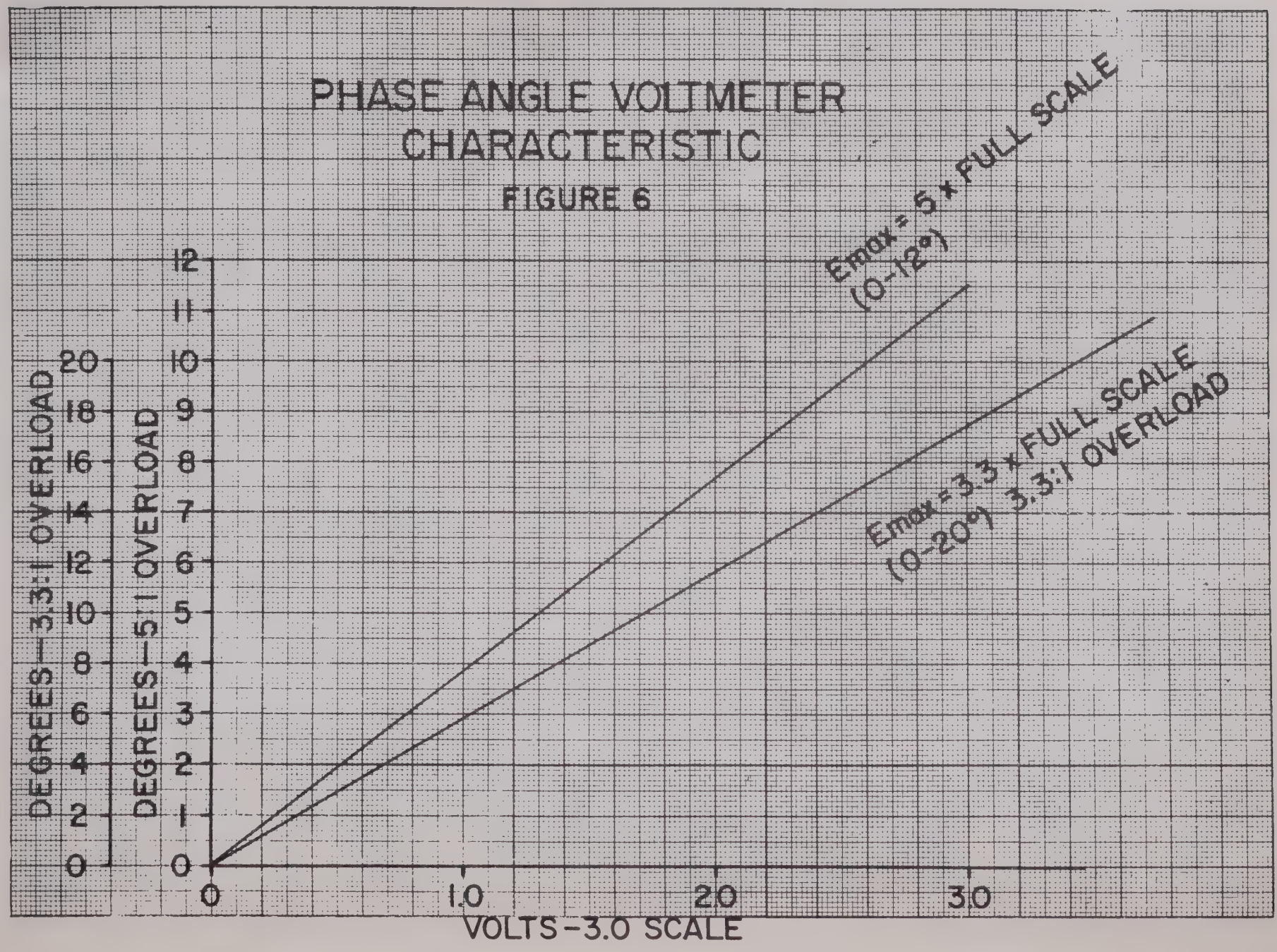

PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES — 3.3:1 OVERLOAD
DEGREES — 5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS - 3.0 SCALE

TABLE II

Max. Voltage	Scale for meas. deg.	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	± 90	2.7 deg.	5
1.0	.3	3.3:1	± 19.5	0.6	6
1.0	.1	10:1*	± 5.7	.2*	5
1.5	1.0	1.5:1	± 41.8	1.3	5
1.5	.3	5:1	± 11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV-PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built in calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V-MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

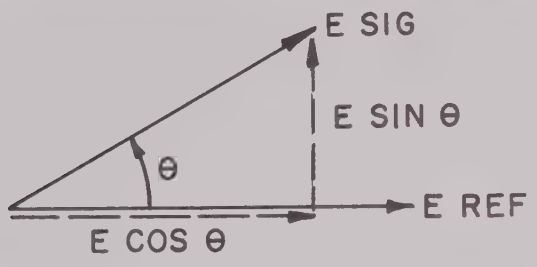


FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure 7 as:

In-phase component = E cos Θ

Quadrature Component = E sin Θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos Θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin Θ. For the greatest accuracy in this type of measurement the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI-MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This measurement is conveniently accomplished by means of the set-up shown in Figure 8. The angle is measured as previously discussed.

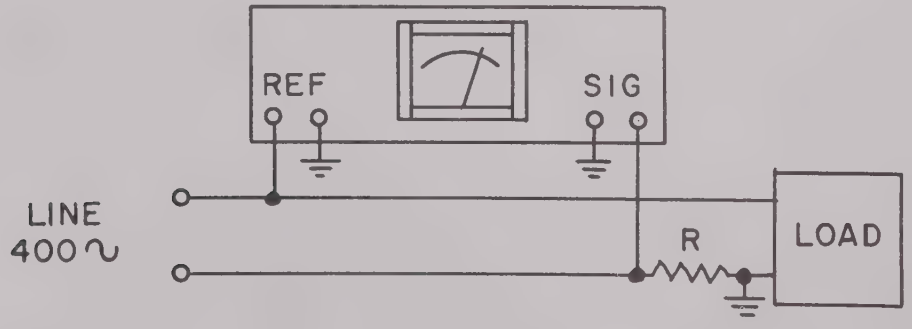


FIG. 8

VII-IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure 9 illustrates the manner in which the measurements can be made.

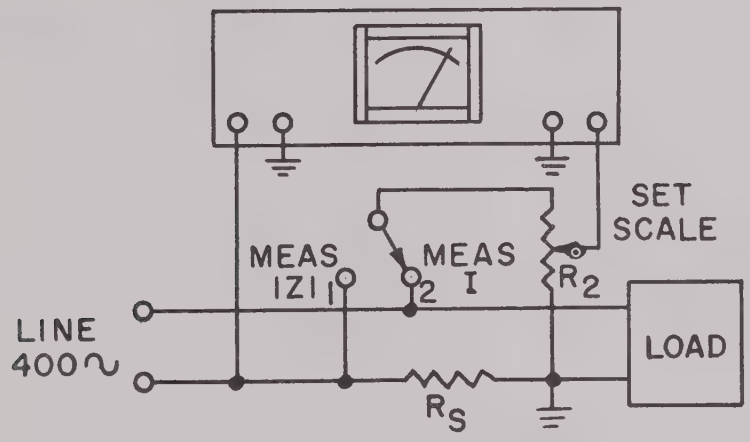


FIG. 9

Using Table III as a guide, a precision ($\leq$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale volts on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE

Load Impedance = 470K

Rs = 1K

E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1 Volt Equals	Current Factor
10K	10K	1/volts
1K	1K	"
100 ohms	100 ohms	"
10 ohms	10 ohms	"
1 ohm	1 ohm	"

Measurement of A.C. Resistance and Reactance

By using the circuit of Figure 9 the real and imaginary components of the impedance can also be measured directly by using the current as a referency and measuring the in-phase and quadrature components of the signal measured with the switch in position 2. The in-phase component will be the A.C. Resistance and the quadrature component will be the reactance with the sign determined as positive for a right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII-APPLICATIONS

Precision Ratiometer

In many analogue computer systems the process of multiplication, division, addition and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure 10 permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

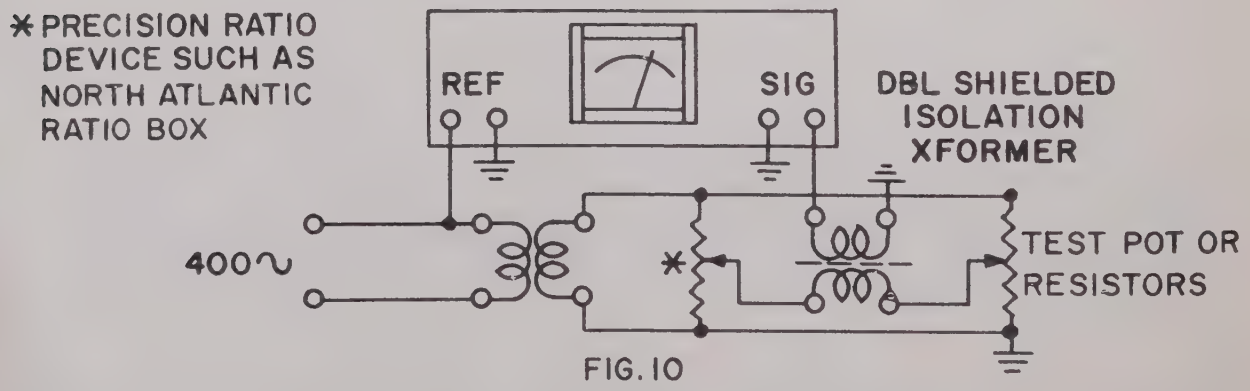


FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance transformer such as a North Atlantic T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

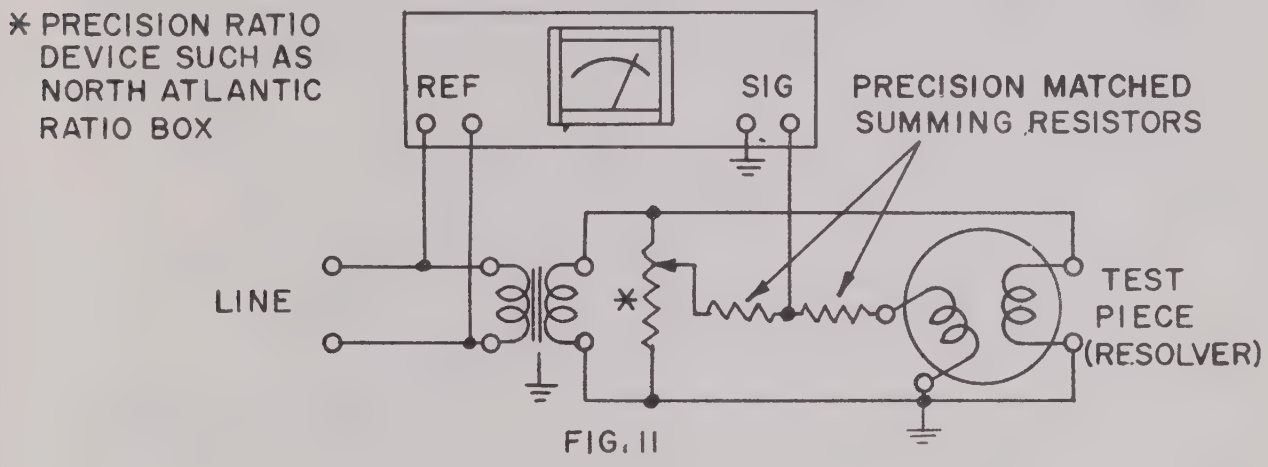


FIG. 11

Transducer Nulling

Applications involving transducers such as differential transformers or E-Coil pickoffs are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure 12 shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

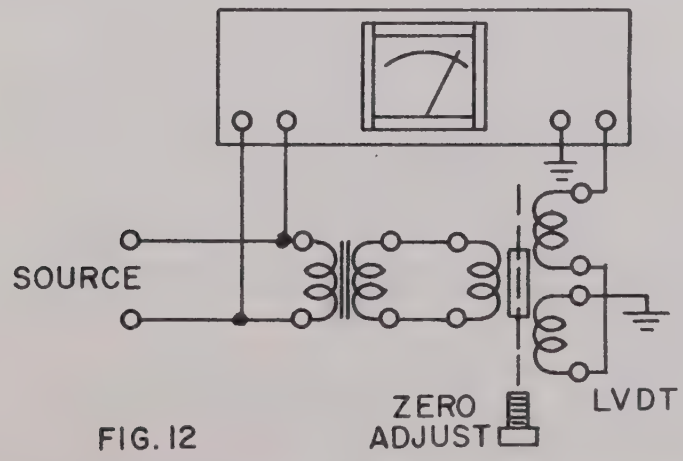


FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure 13 is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible precision nulls unobtainable by conventional instrumentation.

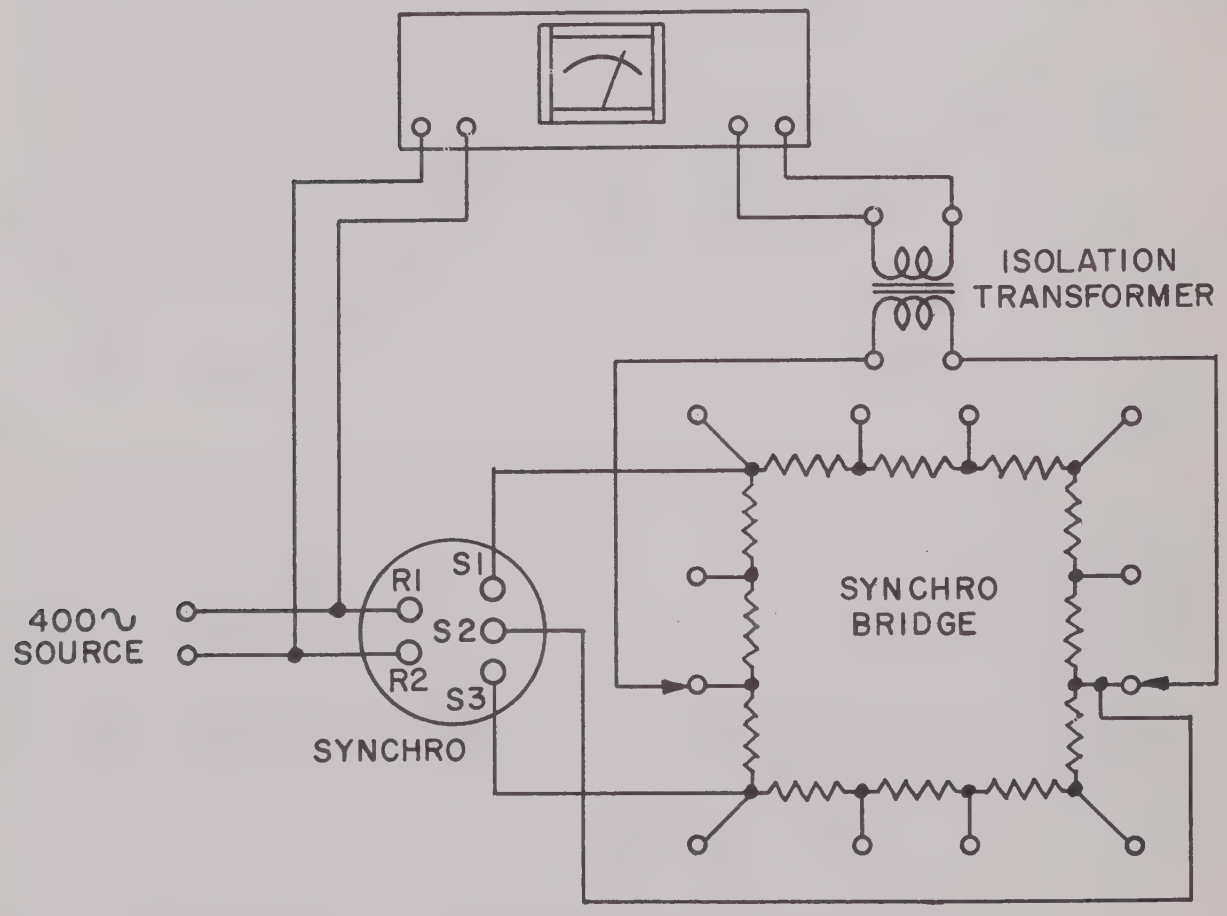


FIG. 13

Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped wave forms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure 14, the task of alignment for maximum torque or output is straight forward since the meter reading is equivalent to motor output.

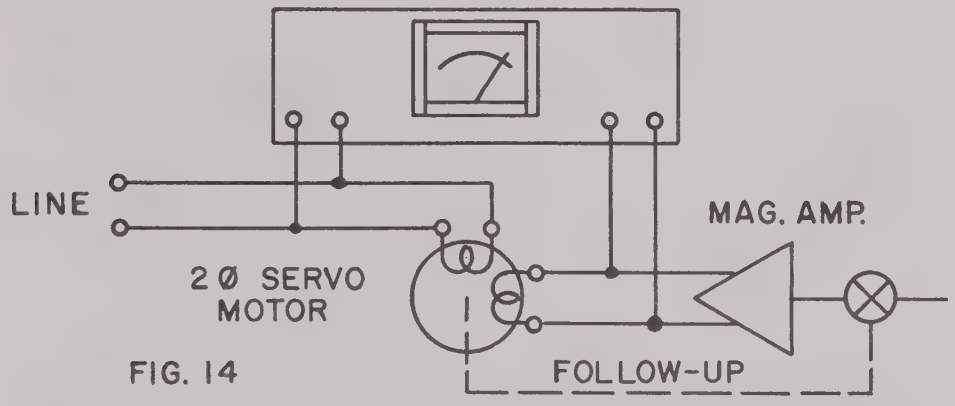


FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc. must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure 15 is a test set-up used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

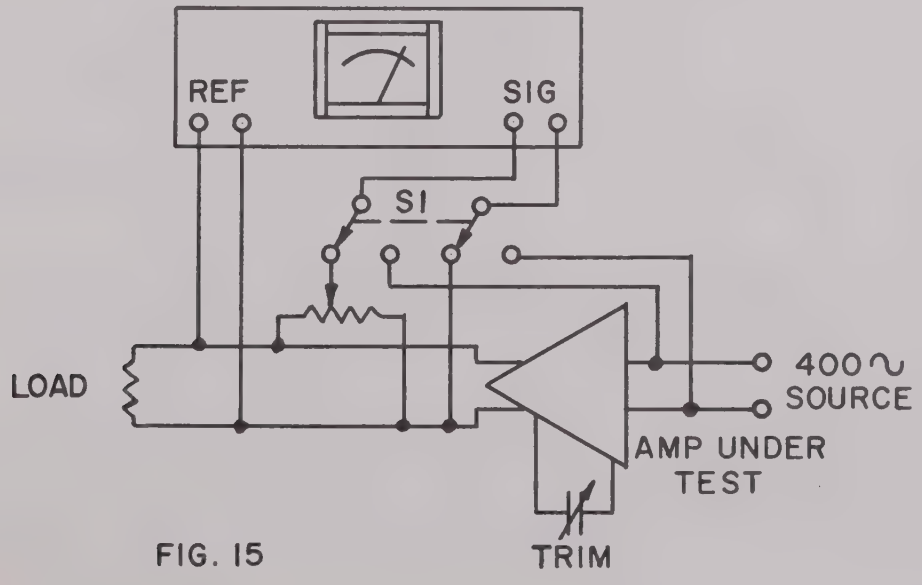


FIG. 15

TRANSFORMATION RATIO

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure 16 (a) and 16 (b).

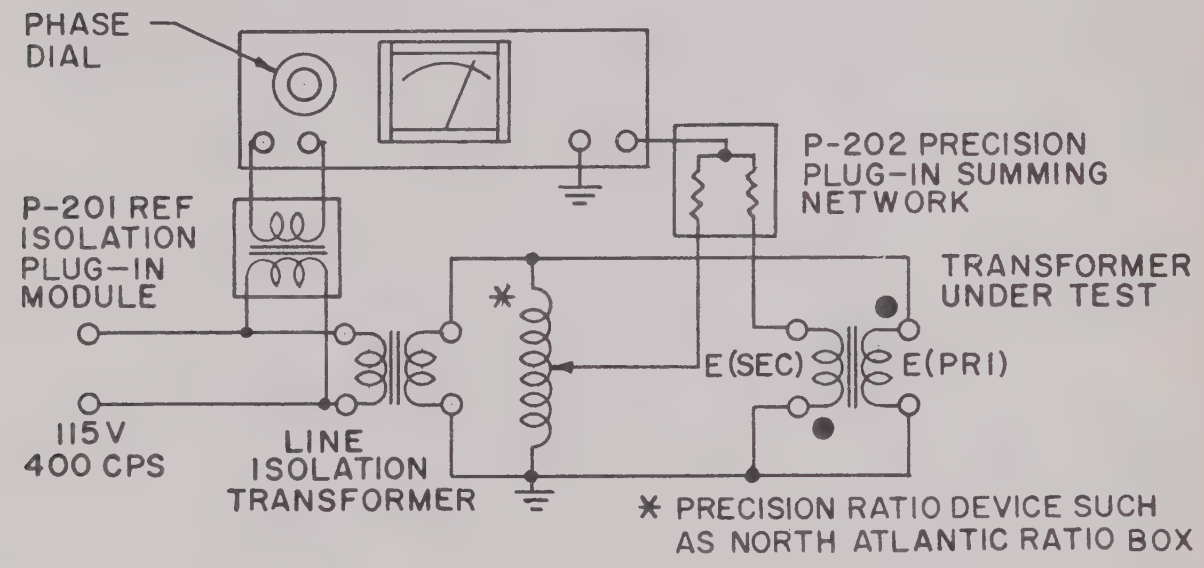


FIGURE 16 (a)

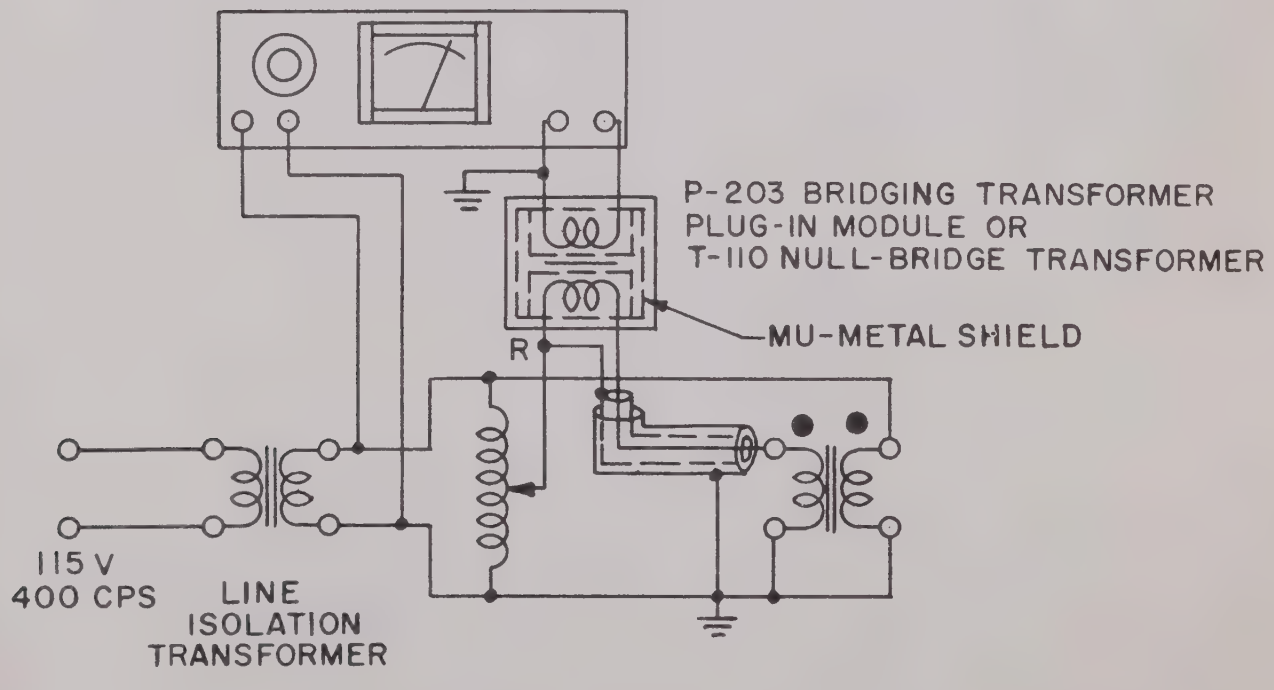


FIGURE 16 (b)

I. SUMMING NETWORK TECHNIQUE

In Figure 16 (a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test set up a line isolation transformer is utilized so as to avoid grounding one side of the line. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure 16 (a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure 16 (b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common mode rejection and low input capacitance would suffice.

Measurement errors in Figure 16 (b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the figure.

Common mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each set up must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both set-ups require that the phase dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc.. This is conveniently done by stepping the ratio device and adjusting the phase dial to produce zero output when the function selector is in the 90° position. Operation will then be correct when the function selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than .01° can also be made using the set ups of Figure 16. The process consists of making the in-phase null, described in the foregoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$